BUREAU OF LAND MANAGEMENT
UTAH

THE TAR SANDS PROJECT: AN INVENTORY AND PREDICTIVE MODEL FOR CENTRAL AND SOUTHERN UTAH

Betsy L. Tipps

with sections by
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and Craig S. Smith

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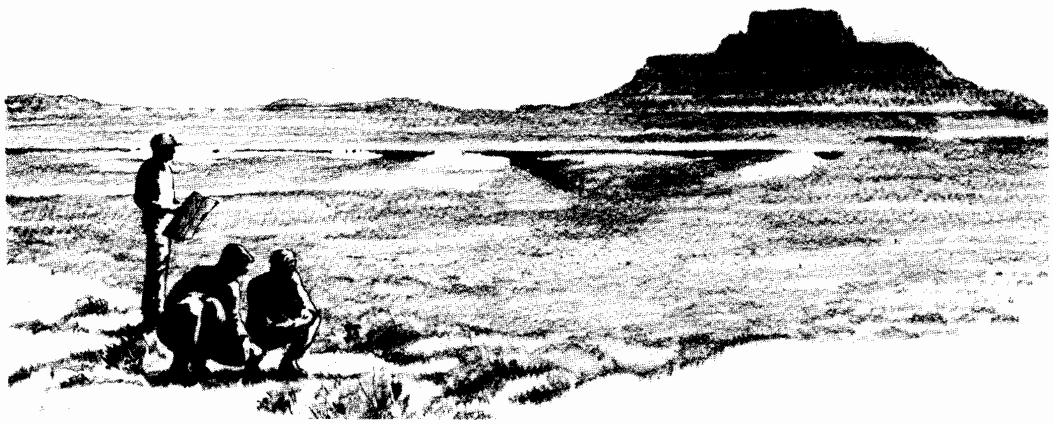

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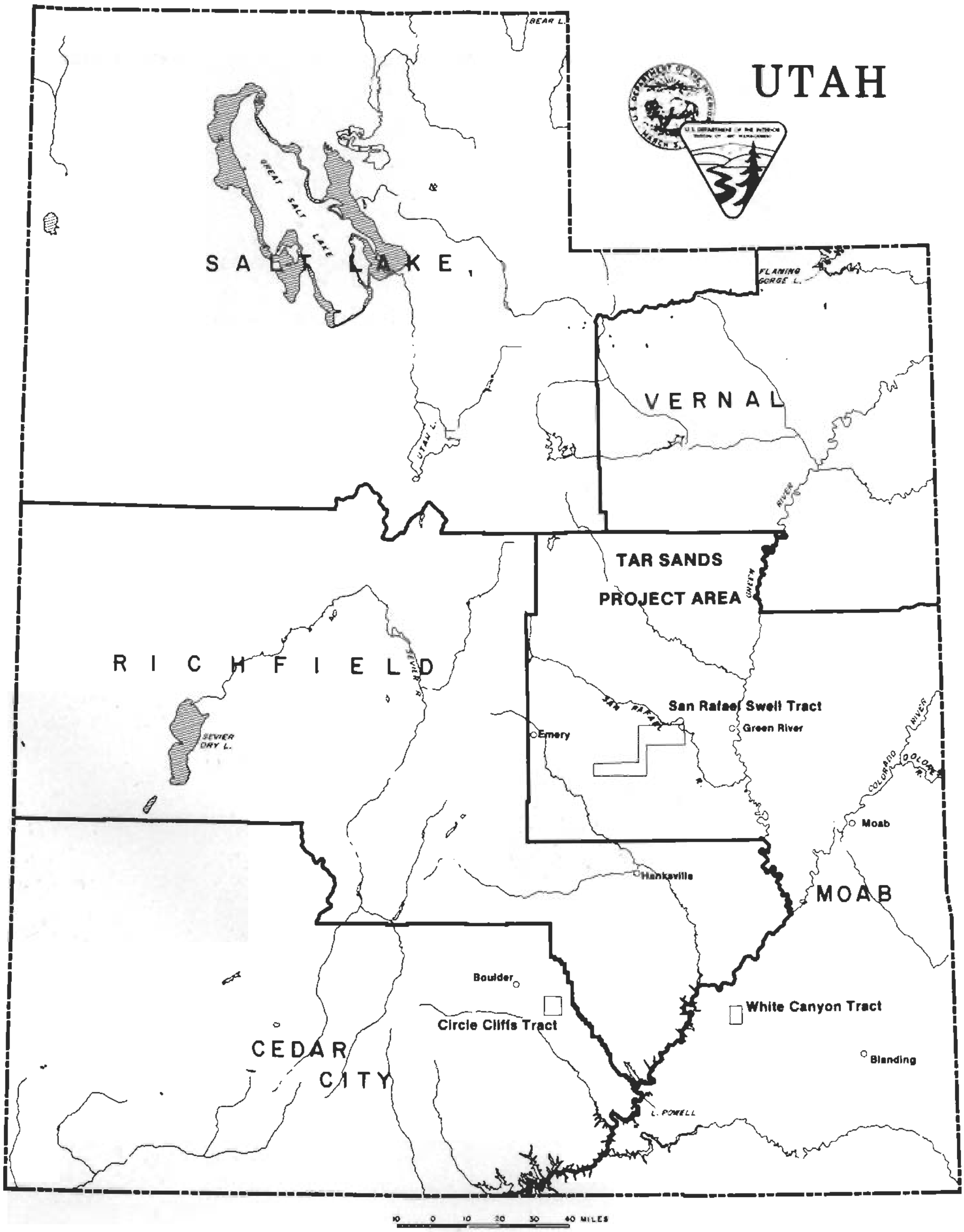

UTAH
BEAR L.
GREAT SALT LAKE
SALT LAKE
FLAMING GORGE L.
VERNAL
UTAH L.
TAR SANDS
PROJECT AREA
RICHFIELD
SEVIER R.
SEVIER DRY L.
SAN RAFAEL R.
San Rafael Swell Tract
Emery
Green River
COLORADO RIVER
DOLORES R.
Moab
Hanksville
MOAB
Boulder
Circle Cliffs Tract
White Canyon Tract
CEDAR CITY
Blanding
L. POWELL
10 0 10 20 30 40 MILES

The Bureau of Land Management is pleased to present Volume 22 in the Utah series of Cultural Resource Monographs, *The Tar Sands Project: An Inventory and Predictive Model for Central and Southern Utah.* Although several years have passed since this report was completed and submitted to the BLM, it still stands as a major contribution to the archaeology of central and southern Utah.

First, the report thoroughly documents the results of surveys in the Circle Cliffs, the San Rafael Swell and White Canyon areas of Utah that were virtually unknown archaeologically prior to the inventory. With the recent decline in energy exploration, it is unlikely that major survey projects will be completed in these regions in the near future. Thus, the results of this project will provide important baseline data on these areas for many years into the future.

The report also includes an application and expansion of Holmer's discriminant analysis program for the classification of northern Colorado Plateau projectile points, a principal components analysis of site type and function, as well as a thorough analysis of site density and distribution. Through these and other analyses, the authors provide a view of prehistoric occupation in three separate desert environments of central and southern Utah, as well as hypotheses about prehistoric occupation that can be tested and refined through future research.

Finally, the modelling efforts effectively illustrate the incremental process by which archaeology advances as a science. Previous modelling efforts were reviewed in an attempt to build a foundation for developing the predictive models presented in this report. With revisions, these models achieved a sufficiently high predictive accuracy to make them useful and important management tools. The models presented in this volume will also serve as a basis for developing and testing predictive models in the future. It is with pleasure that we present this volume to both the professional community and interested casual reader.

Richard E. Fike, Series Editor

ACKNOWLEDGMENTS

This project was funded by the Bureau of Land Management (BLM) under contract YA551-CT3-340038. Craig Harmon, BLM Archeologist, served as the Contract Officer's Authorized Representative. In this capacity, he provided technical direction and support, made several visits to the field, and acted as the interface between the BLM and P-III Associates. We are grateful for his help. We also appreciate the assistance of other BLM archeologists: Richard Fike, BLM State Archeologist, Bruce Louthan, Moab District Archeologist, Gardiner Dalley, Cedar City District Archeologist, and Resource Area archeologists Chas Cartwright, Douglas McFadden and Blaine Miller. These individuals assisted us in various ways and served as reviewers for the work. We also thank Don Coleman, BLM Range Technician, who provided invaluable information on access routes and site locations in Circle Cliffs.

Alan R. Schroedl, Principal Investigator, monitored the overall progress of the project, gave constructive criticism and advice, and developed and tested the predictive model. More important perhaps, he trusted our ability to carry out the project goals and provided encouragement along the way.

A special thanks goes to the field crews who endured the rugged terrain with enthusiasm and good humor and whose hard work and dedication allowed us to complete the fieldwork within the time constraints required by the BLM. Jacki A. Montgomery and Craig S. Smith served as crew chiefs for the duration of the project. Nancy J. Coulam, Kenneth W. Russell and Alan Schroedl served as crew chiefs for a portion of the work. The core crew consisted of Warren B. Church, Peter B. Devine, Denise R. Evans, Debra Foldi, William K. Fushimi, Bradley J. Hearth, Beth E. King and Gary M. Popek. The crew was augmented at various times by Barbara A. Cox, Walter Dodd, Susan J. Kreger, Thegn N. Ladefoged, Suzanna T. Montague and Ronald D. Savage. Brad A. Coutant, Donna P. Hough, Heidi L. Roberts and Patricia L. Thompson joined the field crew for a few days. Janice E. Eberhard and Debra Foldi both accepted the laborious but much appreciated task of cooking for a large crew in a primitive field camp.

The long distances between the three study tracts created special logistical problems that were only solved through the gracious cooperation of several local government officials. Dick Newgren, Capitol Reef National Park; Larry Sip, BLM Hanksville; Dee Hardy and Larry Davis, Anasazi State Park; and Blaine Luke, Green River and Goblin Valley State Parks, allowed us to use their facilities to store vehicles and equipment, leave and pick up messages and obtain water.

We appreciate the assistance of Michael S. Berry and Alan S. Lichty of the University of Utah Archeological Center who extracted and analyzed the Landsat data and developed the Landsat locational model. We are also grateful for Lichty's assistance in entering the IMACS data on the computer and assisting us in our remote terminal processing on the University of Utah computer. Michael Garratt, Bureau of Land Management, and Kenneth Kvamme, University of Denver, reviewed draft copies of Chapters 7 and 8, and made helpful comments.

A number of people assisted during the laboratory phase of the project. Ken Russell compiled the information on historic sites and artifacts included in Chapters 5 and 6. Alan Schroedl performed the discriminant analysis of the projectile points and photographed the artifacts. Various other laboratory tasks were conducted by Mona Baker, Peter Devine, Donna Hough, Gary Popek, Ken Russell, Ron Savage, Craig Smith, Elizabeth Kae Smith and Thegn Ladefoged. Drafting was accomplished by Lynn Harrell, Patrick O'Brien, Ken Russell and Craig Smith. Michelle A. Sanders reviewed various project forms and cheerfully completed the monumental task of typing the site forms and portions of the draft and final reports. The final report was proofread by Sharon S. Arnold and Michelle Sanders.

This report was originally submitted to the BLM in February of 1984. It was reformatted in late 1987 and a few minor editorial changes were made to prepare it for publication. Several people assisted in this effort. Michelle Sanders completed the tedious tasks of proofreading and transferring the report into its present format. Nancy J. Hewitt performed minor editing. Al Lichty resurrected the necessary computer files and translated the color images in the original Landsat study into the black and white figures presented in Appendix 8. Mike Berry provided the text files for this appendix, and John Nielsen prepared the cover art.

We especially thank BLM Archeologists Rich Fike and Craig Harmon for their efforts and assistance in preparing the report for publication. Finally, I thank P-III Associates for providing the facilities, supplies and secretarial help necessary to typeset the report.

Betsy L. Tipps
Project Director

November 1983
and
November 1987

ABSTRACT

This report documents the results of a Class II cultural resource inventory conducted for the Bureau of Land Management in central and southern Utah. This work was necessary to collect information for an Environmental Impact Statement on tar sands development and was conducted in three separate study tracts located in Circle Cliffs, the San Rafael Swell and White Canyon. The project had two main objectives; the first was to locate, record, identify and assess cultural resources within the three study tracts. The second objective was to develop two separate site location models to aid in the management of cultural resources in the project area.

A pedestrian survey of approximately 17,300 acres resulted in the identification of 155 prehistoric and historic sites within the survey area, 54 in Circle Cliffs, 81 in the San Rafael Swell and 20 in White Canyon. Eleven additional sites were recorded outside the actual survey quadrats but inside the project area. Most of the sites are lithic scatters that were used for a short period of time. Several contain evidence of longer, more intensive or repeated use, such as stratified deposits, masonry structures, middens, hearths and pottery. Temporal affiliation ranges from Early Archaic to historic. Cultural groups identified include Archaic, Anasazi, Fremont, Numic and Euroamerican. Fifty sites are recommended as potentially eligible for the National Register of Historic Places.

Two separate site locational models were generated based on the results of the survey: one using map-readable environmental variables, the other using remotely sensed Landsat imagery data. The first model was developed using discriminant analysis and successfully classified over 90% of the quadrats with sites. It should prove to be a valuable tool for management purposes. The Landsat model produced actual probabilities of site occurrence by quasi-environmental strata in each study tract. Its utility for management purposes is more limited than the discriminant model.

PREFACE

This document is the final report of a Class II cultural resource inventory and modelling effort conducted for the Bureau of Land Management in central and southern Utah. This project is the most recent in a long series of sample cultural resource inventories completed in the state of Utah over the past decade. During this time, field inventory standards have been raised to new professional levels as reflected by more complete and standardized site forms, more accurate maps and better descriptions of artifacts and features. The overall quality of recent reports demonstrates these procedural advances.

As methodological aspects of archeology are being honed and refined, so too are new theoretical approaches to understanding the past. Perhaps on the forefront of new theoretical approaches is site locational modelling. In the past decade, it has become clear that federal lands will be developed at ever-increasing rates. Yet, the scope of these developments will often exceed budgetary allotments for cultural resource studies. Thus, it comes as no surprise that land managers have eagerly supported predictive modelling as a means of extending their limited budgets for managing the ever-dwindling resource base and expanding our knowledge of prehistoric cultural groups.

Capitalizing on the efforts of previous researchers, we developed a predictive model of site location that will be highly successful in predicting site presence and absence in uninventoried portions of the project area. Our preliminary results suggest that the accuracy rate could exceed 90% on future applications.

In a larger, research-oriented sense, the modelling effort has addressed a number of theoretical and methodological issues. It demonstrated that site location prediction is, at best, a difficult and complicated undertaking. It also showed that the unquestioned application of statistical programs does not automatically produce a successful predictive model. It is necessary to consider measurement error, adjust for "noise" and evaluate the structure of the data before a final model can be developed.

Likewise, our efforts have demonstrated the absolute necessity of testing all predictive models with an independent and representative data set. Our investigations as well as those of previous researchers clearly show that the correct rate of classification obtained by the initial model will always be greater than its actual predictive ability. Researchers should be aware of this problem and should not present the results of their initial self-classification rates as evidence of high predictive accuracy.

It is evident, based on all of the previous research efforts directed at site location modelling, that we are only now beginning to understand the critical factors and variables that influence and correlate with site locations. It is hoped that the results of this project will suggest several new avenues for fruitful research in future modelling efforts.

Alan R. Schroedl
Principal Investigator

November 1983

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Chapter 1

INTRODUCTION

During the summer of 1983, P-III Associates, Inc., conducted a two phase, cultural resource inventory of approximately 27 square miles of public land in central and southern Utah. This work was conducted for the Bureau of Land Management (BLM) under contract YA551-CT3-340038 to obtain information on cultural resources for an Environmental Impact Statement on tar sands development. It was also necessary to help the BLM fulfill their legal obligations concerning cultural resources.

These obligations require the BLM to locate, assess and protect cultural resources on BLM administered land, and to ensure that significant properties are not damaged or destroyed by federally licensed, funded or initiated activities. These legal responsibilities are mandated by various laws including the Antiquities Act of 1906, the Historic Sites Act of 1935, the National Historic Preservation Act of 1966, the National Environmental Policy Act of 1969, the Federal Land Policy and Management Act of 1976, Executive Order 11593 and the Archeological and Historic Preservation Act of 1974.

Location

The project area consists of three geographically separate study tracts located in Circle Cliffs, the San Rafael Swell and White Canyon, and includes approximately 172,000 acres of BLM and State of Utah land in central and southern Utah (Figure 1). The Circle Cliffs tract is roughly crescent shaped and includes approximately 50,300 acres of BLM land in Garfield County east of Boulder, Utah. It is bound by Studhorse Peaks on the north, the Waterpocket Fold and Capitol Reef National Park on the east, Glen Canyon National Recreation Area and Horse Pasture Mesa on the south and Circle Cliffs on the west and southwest. It lies in the Kanab Resource Area of the Cedar City BLM District.

The San Rafael Swell tract encompasses approximately 111,200 acres of BLM land and is situated in the Moab District, Price Resource Area. Located in Emery County, it consists of six discontiguous blocks of land straddling Interstate 70 west of Green River, Utah. More specifically, this study tract lies south and southwest of the San Rafael River, west of the San Rafael Reef, north and northwest of Temple Mountain and Goblin Valley State Reserve and east of Sagebrush Bench and Cane Wash.

The White Canyon tract incorporates approximately 10,500 acres of BLM and State of Utah land, and lies north of Fry Canyon, in San Juan County, Utah. It is rectangular in shape and straddles Utah Highway 95 between White Canyon and Lost Canyon. It trends in a northeast/southwest direction generally following the Short Canyon drainage system. The BLM land in this tract is administered by the Moab District, San Juan Resource Area. Additional discussions concerning the location and physical environment of each study tract are presented in Chapter 2.

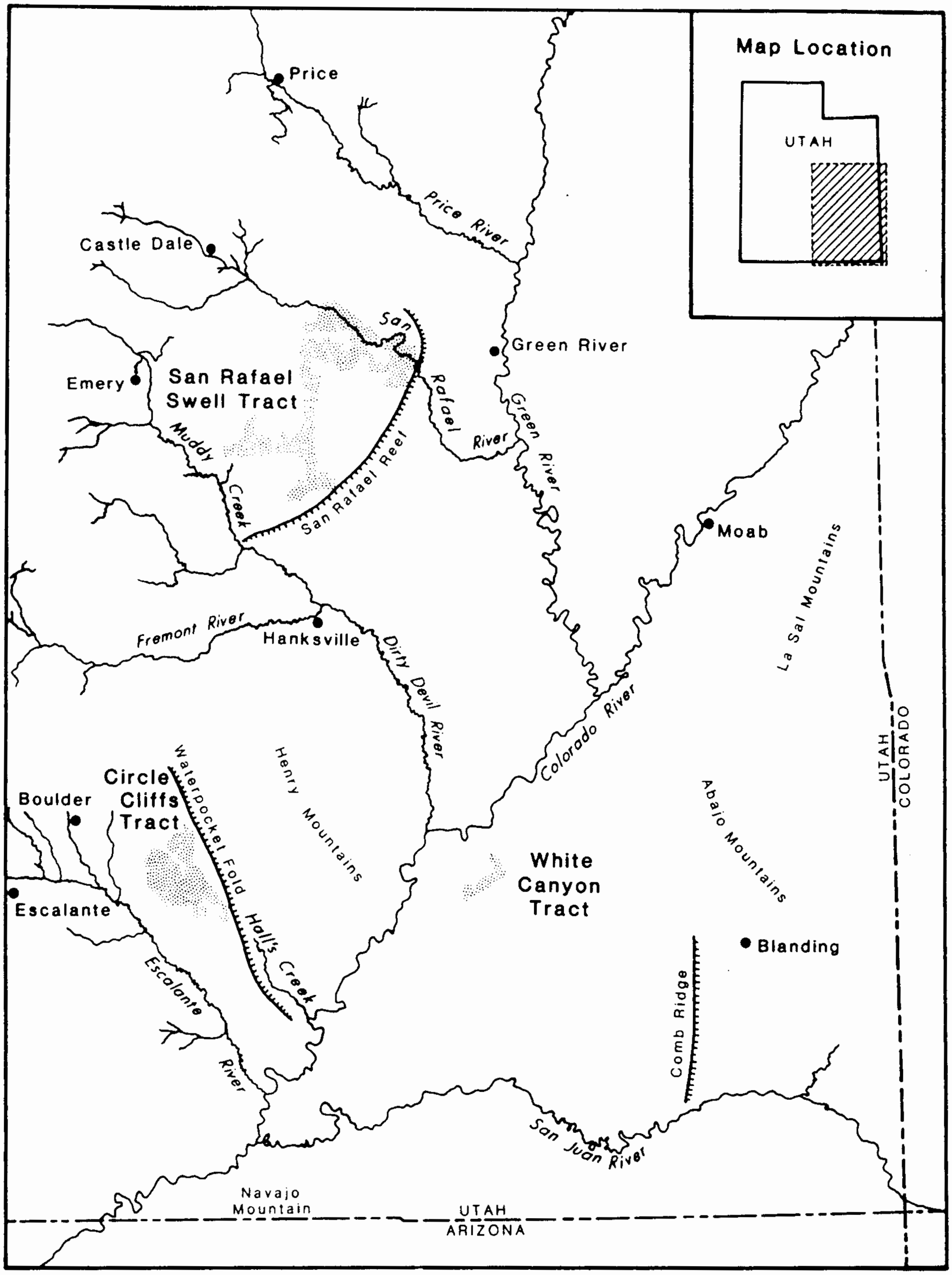

Figure 1. Map of southeastern Utah showing the location of the study tracts and major physiographic features.

Objectives

The specific objectives of the project, as specified in the Statement of Work, were to

1. conduct a cultural resources inventory of 5% of each study tract,
2. develop a site locational model based on correlations between environmental characteristics and known site locations,
3. inventory an additional 5% of each study tract, and
4. test and refine the model with data generated by the second 5% survey.

In addition to the specific goals noted above, the general objectives were to "define the nature and diversity of the resource . . . develop projections of expected density, distribution and diversity of cultural resources based on a 10% Class II sample . . . define factors which determine cultural resource site selection . . . determine what factors have explanatory value for predicting the location of sites . . ." and ". . . define research directions for the project area that will provide a basis for formulating and evaluating mitigation plans, as well as guidance for future archaeological program needs" (U.S. Department of Interior, Bureau of Land Management 1983:24-25).

Results

The survey was conducted between May 25 and July 29, 1983, by a crew ranging from 13 to 18 individuals. Alan R. Schroedl served as the Principal Investigator. Betsy L. Tipps was the Project and Field Director. Nancy J. Coulam, Jacki A. Montgomery, Kenneth W. Russell, Alan R. Schroedl, Craig S. Smith and Betsy L. Tipps served as crew chiefs during the project. Craig Harmon, BLM Archeologist, was the Contracting Officer's Authorized Representative.

Approximately 27 square miles were surveyed during the project, 16,800 acres within the 105 160-acre quadrats and approximately 500 acres as buffer zones. The crews recorded 155 prehistoric and historic sites within the survey quadrats and 11 additional sites in the buffer zones, bringing the total to 166 previously unrecorded sites. Chapter 4 describes the field methods used to locate and record the sites. Chapter 5 summarizes their cultural and chronological affiliation, suspected function and National Register eligibility. Fifty (32%) of the 155 sites recorded in the survey quadrats are considered potentially eligible to the National Register of Historic Places.

Two hundred and eighty-four isolated finds were also recorded during the project, 274 in the survey quadrats and 10 in adjacent buffer areas. Within the survey quadrats, a total of 26.25 square miles was surveyed resulting in an average of 1.48 sites and 2.61 isolated finds per quarter section. Chapter 7 discusses these averages, site density projections and associated confidence intervals in greater detail.

In the Circle Cliffs tract, the survey area consisted of 30 160-acre quadrats, 15 in each 5% sample. The inventory resulted in the discovery of 54 prehistoric and historic sites and 62 isolated finds. An additional eight sites and seven isolated finds were discovered and recorded while locating the quadrats or surveying buffer zones. Twelve of the 54 sites (22%) in the quadrats and 1 site outside of the quadrats are considered potentially eligible to the National Register. The average density of prehistoric and historic sites in Circle Cliffs is 1.80 sites per quadrat.

In the San Rafael Swell study tract, the survey included 68 160-acre parcels, 34 in each 5% sample. A total of 81 prehistoric and historic sites and 185 isolated finds was discovered in the quadrats, with an additional 3 sites and 3 isolated finds being found outside the quadrat boundaries but inside the project area. Site density averages 1.19 sites per quarter section. Twenty-eight sites within the survey quadrats are believed to be potentially eligible to the National Register.

Due to the small size of the White Canyon tract, a single 10% sample was inventoried encompassing seven 160-acre quadrats. Twenty previously unrecorded sites and 27 isolated finds were found during the inventory. Ten sites, or 50%, are considered potentially eligible to the National Register. Average site density in White Canyon is 2.86 sites per quarter section.

The 155 sites recorded in the survey quadrats represent 167 components: 29 Archaic, 6 Fremont, 17 Anasazi, 3 Numic, 9 Euroamerican and 103 unknown. The Anasazi sites are located in the White Canyon tract; ceramic evidence suggests that they may be of Kayenta affiliation. Sites identifiable as Fremont are restricted to the San Rafael Swell and lie within the geographical boundaries of the San Rafael variant (cf. Marwitt 1970). Numic and Euroamerican sites occur in both Circle Cliffs and the San Rafael Swell, with the latter being indicative of ranching, mining and perhaps hunting activities. Archaic sites are found in all three areas.

As discussed in Chapter 5, a wide range of site types was found including lithic scatters, sherd and lithic scatters, rockshelters, buried sites and subterranean pithouses. The sites vary in size, feature composition and artifact density and diversity, ranging from small, limited activity loci to extended habitations, some with roomblocks and masonry structures. The features and artifacts discovered on these sites are described and discussed in Chapter 6.

Two separate models of site location were developed to fulfill the requirements of the contract. The first, based on map-readable environmental variables such as slope, elevation and distance to water, uses discriminant analysis to segregate quadrats with sites from quadrats without sites. Classification functions for this modelling effort were derived using survey data from the first 5% sample and tested with data from the second 5% sample. Several refinements were made to this model in order to produce a highly successful revised model. This model, based on a three group solution, correctly classified over 90% of the survey quadrats containing sites.

The second predictive model was generated by the University of Utah Archeological Center using multispectral Landsat data. It differs from the preceding model in that quasi-environmental strata were empirically derived, and probabilities of site presence were then assigned to each stratum. While this effort achieved its purpose of identifying strata and assigning probabilities, its utility for management purposes is limited because most of the strata have similar probabilities of site occurrence. Discussions of both modelling efforts, interpretations and comparisons of the results are discussed in Chapter 8.

Chapter 9 summarizes the research results of this project and outlines directions for future work. It also includes general conclusions about the survey and models, and presents recommendations for the management of cultural resources in the three study tracts.

Chapter 2

Environmental Setting

by Craig S. Smith

To provide background information for interpreting the results of this survey, the physiography, geology, climate, vegetation and animals of the overall project area are summarized below. Following this general introduction, the environmental setting of each study tract is discussed in more detail.

All three study tracts are located in the Canyon Lands Section of the Colorado Plateau physiographic province, on or near large upwarp features (Hunt 1974). This region is a semi-arid, cool desert/desert woodland and lies within the Shadscale, Sagebrush and Pinyon-Juniper vegetation zones (Cronquist et al. 1972). Permian, Triassic and Jurassic sedimentary rocks are exposed in all three study tracts; the primary substrate, however, is the Triassic Moenkopi Formation. This shaley sandstone formation erodes into a dissected badland topography which is relatively unsuitable for human habitation.

General Overview

Physiography and Geology

The Canyon Lands Section of the Colorado Plateau is characterized by uplifted, stacked layers of pre-Tertiary sedimentary rocks (Hunt 1974). Wind and water erosion coupled with folding and faulting have sculpted the area on a massive scale leaving a country of ridges, structural upwarps, terraced plateaus, cliff-bound mesas and deeply entrenched, vertical walled canyons. Rising above the dissected sedimentary rock plateaus are the Henry, Abajo and Navajo laccolithic mountains.

Large structural upwarps and basins, created by folding and faulting during the Tertiary era, are pronounced features on the plateau landscape. These upwarps, the Circle Cliffs, the San Rafael Swell and the Monument, are asymmetrical anticlines characterized by gently sloping flanks on the west and steeply dipping flanks on the east. The oldest layers of sedimentary rocks usually are exposed along the crest of the anticline, where the younger strata have been stripped away by erosion (Baars 1972). Along the steeply tilted eastern flanks, the younger strata frequently develop massive ridges. In addition to the steep-sided canyons and cliffs which occur throughout the area, these massive ridges, generally known as hogbacks or "reefs," create nearly impassable barriers in many portions of the Canyon Lands Section (Hunt 1974).

Geologic strata exposed throughout the region are primarily the Permian through Cretaceous formations of water- or wind-deposited sandstones, limestones, shales and mudstones (Table 1). Formations such as the Wingate and Navajo sandstones form massive cliffs that often extend for miles. The weak shaley sandstones of the older Moenkopi and Chinle formations erode into steep talus slopes and cover the valley flats. The Chinle

Table 1. Geological formations exposed in or near the project area.

System	Formation	Lithology
Cretaceous	Mancos Shale	Gray marine shale
	Dakota Sandstone	Littoral sandstone
Jurassic	Morrison Formation	Fluvial deposits of clay and shale, variegated sandstones and conglomerate
	San Rafael Group:	
	Summerville Formation	Evenly bedded, reddish brown sandstone and sandy shale
	Curtis Formation	Marine, evenly bedded, gray sandstone and shaley sandstone
	Entrada Sandstone	Thick, cross-bedded, buff sandstone
	Carmel Formation	Thin bedded, red sandstone, shaley sandstone, shale, limestone and gypsum
Triassic	Glen Canyon Group:	
	Navajo Sandstone	Tan to light gray, massive, cross-bedded sandstone
	Kayenta Formation	Sandstone and shaley sandstone
	Wingate Sandstone	Massive, cross-bedded, cliff forming sandstone
	Chinle Formation	Variegated sandstone, shale, limestone and conglomerate
	Shinarump Conglomerate	Cross-bedded sandstone and conglomerate
	Moenkopi Formation	Red and buff sandstone and red shale, some limestone
Permian		
(In the San Rafael Swell and Circle Cliffs areas)		
	Kaibab Limestone	White buff and light gray limestone
	Coconino Sandstone	Light-colored sandstone
(In the White Canyon area)		
	Cutler Formation:	
	Organ Rock Member	Red sandstone and sandy shale
	Cedar Mesa Sandstone	Cream-white to yellow-brown, cross-bedded sandstone

SOURCES: Gilluly 1929; Gregory and Moore 1931; Hunt 1974

Formation, which occurs throughout the project area, contains pockets of cherts, chalcedonies and petrified wood, important sources of stone for the prehistoric inhabitants. Alluvial sediments, gravels and sand dunes of Quaternary age also occur in selected portions of the project area.

Hydrology

Large perennial streams of the Colorado River drainage system, including the Colorado, Green, Escalante, Dirty Devil and the San Juan rivers, flow through deeply entrenched canyons and essentially divide the plateau region into a number of areas. Although these rivers are a major source of water in this semi-arid to arid region, water also occurs in seeps and springs, and after rains in the natural "tanks" eroded into the sandstone strata. Other erosional features found in some of the sandstone outcroppings are overhangs and alcoves that provided natural shelters for aboriginal populations.

Climate

In the vicinity of the project area, the Canyon Lands Section is a semi-arid, cool desert/desert woodland characterized by low precipitation, a high evapo-transpiration rate and a moderately high mean annual temperature (cf. Tipps 1983). The great climatic variability across the region is generally controlled by the elevation and position of topographic features. The mean annual precipitation increases with elevation, but averages around 20 to 30 cm per year in the project area (Jeppson et al. 1968). Although most areas receive at least some snowfall every year, the precipitation usually falls as sporadic, short-lived thundershowers during late summer. August is generally the wettest month with the driest season occurring between April and June. This seasonal distribution of precipitation is the critical factor for the prehistoric practice of dry farming.

The average temperature for the region generally decreases as altitude increases. In the lower elevations, maximum temperatures may reach at least 38° C (100° F) during July, while in the higher country, the maximum temperatures for July are below 27° C (80° F). The maximum temperatures for January range from about 4° C (40° F) in the lower areas to about -4° C (25° F) in the higher elevations (Jeppson et al. 1968). The minimum temperatures are -7° C (20° F) in January and 21° C (70° F) in July for the lower elevations and -7° C (20° F) in July at higher elevations. Temperatures may vary more than 40 degrees in a 24-hour period. The length of the growing season varies with elevation from over 200 days at Hite (1060 m) on the Colorado River to around 120 days at Escalante (1760 m [Gregory and Moore 1931:23]). The study tracts have approximately 150 to 180 frost-free days a year.

Vegetation

The project area lies within the Great Basin Floristic Province (Gleason and Cronquist 1964) and has flora similar to the rest of the Intermountain Region. Within this province, numerous plant communities occur as a result of the great diversity of topography and climate across the region. These communities are usually lumped into vegetation zones according to altitudinal differences (Cronquist et al. 1972; Tidestrom 1925). Following Billings (1951), who described the vegetation of the Great Basin, Cronquist et al. (1972) recognize the following zones from low to high elevations in the project area: Shadscale, Sagebrush, Pinyon-Juniper and the various Montane zones. There is considerable overlap and intergrading between these zones.

The Shadscale Zone, named for the dominant species, *Atriplex confertifolia*, occupies lower elevation valleys and is typically dominated by low, widely spaced, small-leaved shrubs. Besides shadscale, other common shrubby species include bud sagebrush (*Artemisia spinescens*), four-wing saltbush (*Atriplex canescens*), rabbitbrush (*Chrysothamnus viscidiflorus*), Mormon tea (*Ephedra nevadensis*), hopsage (*Grayia spinosa*), snakeweed (*Gutierrezia sarothrae*), gray molly (*Kochia americana*) and horsebrush (*Tetradymia glabrata*). Perennial grasses consist of Indian rice grass (*Oryzopsis hymenoides*), galleta grass (*Hilaria jamesii*) and needlegrass (*Stipa speciosa*), among others.

Several plant associations, which are controlled by differences in tolerance to soil salinity and aridity, occur within the Shadscale Zone. One of the more important is the greasewood (*Sarcobatus vermiculatus*) association. Greasewood, a major phreatophyte, occupies saline soils in close proximity to the water table. Other associations found in the project area include the winter fat (*Eurotia lanata*) and the sandsage (*Artemisia filifolia*) communities. The blackbrush community, included within the Shadscale Zone by Cronquist et al. (1972), is most common at low altitudes along the Colorado River drainage system and grows on arid, often sandy soils.

The Sagebrush Zone lies at slightly higher elevations where the annual precipitation is greater. Along with big sagebrush (*Artemisia tridentata*), other important shrubs include low sagebrush (*Artemisia arbuscula*), rabbitbrush (*Chrysothamnus nauseosus*), Mormon tea (*Ephedra viridis*), antelopebrush (*Purshia tridentata*) and hopsage (*Grayia spinosa*). Occurring as codominants with the sagebrush are such grasses as wheat grass (*Agropyron spicatum*) and bluegrass (*Poa sandbergii*). Also grouped into this zone is the galleta-three awn shrubsteppe community, which covers large areas in the Canyon Lands Section (Cronquist et al. 1972).

The Pinyon-Juniper Zone (*Pinus edulis* and *Juniperus osteosperma*) occupies high plateaus in the Canyon Lands Section. Although big sagebrush is the most common understory shrub of this woodland, other shrubs including mountain mahogany (*Cercocarpus ledifolius*), rabbitbrush (*Chrysothamnus nauseosus*), cliffrose (*Cowania mexicana*), Mormon tea (*Ephedra viridis*), snakeweed (*Gutierrezia sarothrae*) and antelopebrush (*Purshia tridentata*) are more frequent in much of the project area. Often, the pinyon-juniper woodland occurs with only a sparse understory.

Growing along many of the water courses throughout all of the zones are cottonwood (*Populus angustifolia*), willow (*Salix* spp.) and the exotic salt cedar (*Tamarix pentandra*). The Montane zones, found in the mountains above the study tracts, contain from low to high elevation, the Ponderosa Pine, Douglas Fir-White Fir-Blue Spruce and the Engelman Spruce-Subalpine Fir zones.

A variety of taxa in the various vegetation zones would have provided important economic resources to the aboriginal inhabitants. The pinyon nut, an important food resource, was collected during the fall in the Pinyon-Juniper Zone. Many of the understory plants in the Pinyon-Juniper Zone, such as buffaloberry (*Shepherdia argentea*) and cactus, yielded edible fruits that were both eaten fresh and dried for winter use. Firewood and construction materials were also gathered in this zone (Kelly 1964; Steward 1938).

The lower elevation vegetation zones provided various seeds, including those of saltbush, sunflower (*Helianthus* spp.) and peppergrass (*Lepidium* spp.) as well as fruits from yucca (*Yucca* spp.) and other plants (Bye 1972; Steward 1938; Whiting 1939). Indian rice grass, wheat grass and other grasses, common in the area, were also important foods. Tools, baskets and other items were produced from a variety of plants.

Animals

Large mammals that probably inhabited the study area prehistorically include bison (*Bison bison*), mule deer (*Odocoileus hemionus hemionus*), pronghorn antelope (*Antilocapra americana*) and desert bighorn sheep (*Ovis canadensis*). Evidence from Sudden Shelter (Jennings et al. 1980) suggests that deer was more important during the early periods of the Archaic, while bighorn sheep became more important in the Late Archaic. Bones of bighorn sheep dominate the assemblages from prehistoric Pueblo sites along the Colorado River in the Glen Canyon area (Jennings 1966). Pronghorn remains also occur in prehistoric sites in the area (Tipps 1983).

Other mammals occurring in the general study area include coyote (*Canis latrans*), red fox (*Vulpes fulva*), gray fox (*Urocyron cinereoargenteus*), ringtail (*Bassariscus astutus*), badger (*Taxidea taxus*), striped skunk (*Mephitis*

mephitis), spotted skunk (*Spilogale gracilis*), porcupine (*Erethizon dorsatum*), white-tailed jackrabbit (*Lepus townsendi*), black-tailed jackrabbit (*Lepus californicus*), mountain cottontail (*Sylvilagus nuttalli*), prairie dog (*Cynomys parvidens*) and various rodents (Durrant 1952). Among these, the jackrabbit was probably one of the most important resources for the aboriginal inhabitants of the area because it provided both fur and meat (Beaglehole 1936; Kelly 1964; Steward 1938). In addition to food, many of the mammals provided materials for clothing, moccasins, tools and other items for both the Pueblo peoples and the Paiute (Beaglehole 1936; Kelly 1964).

Numerous species of birds, including water fowl, as well as various fish and reptiles also are common in the project area. Grasshoppers, according to Gregory and Moore (1931:27), occur in the area in sufficient quantities to have been a viable food resource.

Circle Cliffs

The Circle Cliffs study tract (Figures 2-4) is situated near the central portion of the Circle Cliffs Upwarp, an elongated asymmetric anticline about 80 km in length (Gregory and Moore 1931). The elongated upwarp feature, compressed from east to west, parallels the Waterpocket Fold monocline which borders it on the east. Erosion of the upwarp has produced a broad elliptical valley surrounded on all sides by massive inward facing cliffs and benches of Wingate sandstone. These cliffs and the Waterpocket Fold provide imposing, although not impenetrable barriers, to travel through the region.

The Circle Cliffs valley consists of dissected tablelands with shaley sandstone ridges and remnant mesas. Areas between the mesas often contain alluvial deposits and occasional sand dunes. North/south flowing drainages including Moody Creek, Silver Falls and Death Hollow bisect the high benches surrounding the valley, thus providing access through the area.

Although the elevation ranges from 1675 m along the southern and western edges of the Circle Cliffs valley to about 2195 m on top of Wagon Box Mesa, most of the study tract lies between 1830 and 1980 m in elevation. To the west of the Circle Cliffs area, the terrain slopes steadily up towards the higher Aquarius Plateau. To the southwest, beyond the Escalante River, rise the Straight Cliffs of the Kaiparowits Plateau.

The geologic strata exposed in the study tract range from the Permian sandstones and limestones of the Coconino and Kaibab formations to the Upper Triassic Wingate Formation, although the Triassic Moenkopi Formation predominates (Gregory and Moore 1931). Mesas in the center of the Circle Cliffs valley, such as Wagon Box Mesa and Studhorse Peaks, consist of Moenkopi Formation talus slopes capped by the Shinarump Conglomerate. The younger Chinle Formation is exposed below the Wingate cliffs on the slopes of the mesas near the edge of the valley. Several of the larger drainages that cross the area have cut into the older Kaibab Limestone forming steep canyons.

The major perennial stream for the region, located about 10 km southwest of the study tract is the Escalante River, a tributary of the Colorado River. Most of the drainages that pass through the Circle Cliffs area are intermittent tributaries to the Escalante River and are dry most of the year. Halls Creek, an intermittent stream located about 5 km east of the Circle Cliffs area, follows the trend of the Waterpocket Fold as it flows in a southerly direction to the Colorado River. With the lack of perennial streams in the Circle Cliffs study tract, water is available mainly from a few seeps and springs that dot the area. Another source of water is the saucer-like depressions or "tanks" eroded into Wingate sandstone that occurs on the mesa tops surrounding the study tract and in the limestone bedrock exposed in the deeply cut drainages.

In the Circle Cliffs study tract, vegetation is generally a pinyon-juniper woodland with a sparse understory. This understory includes Mormon tea, snakeweed, buffaloberry, sagebrush and rabbitbrush. In many of the level alluvial valleys, open, grassy areas are surrounded by woodlands while the steeper mesa slopes are barren. Indian rice grass and other grasses important to the prehistoric people of the area grow on the more sandy deposits.

Figure 2. The Circle Cliffs area showing some of the Wingate cliffs that encircle the valley and the pinyon-juniper vegetation.

Figure 3. The Wagon Box Mesa area in the Circle Cliffs study tract showing the rolling, pinyon-juniper-covered ridges.

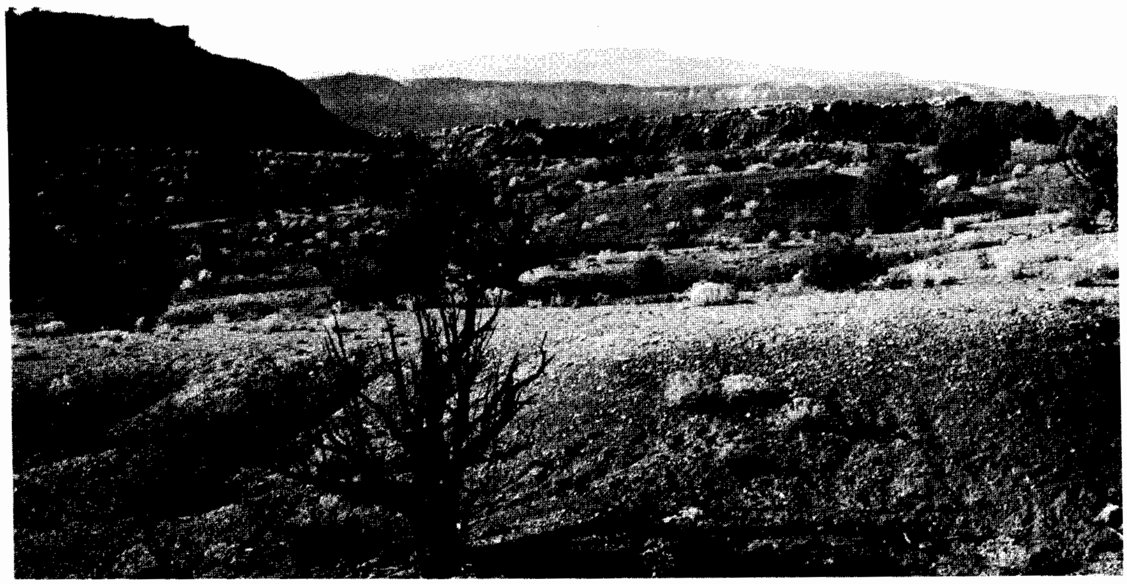

Figure 4. Horse Canyon in the Circle Cliffs study tract showing the sparse pinyon-juniper woodland with a snakeweed understory.

San Rafael Swell

The San Rafael Swell study tract (Figures 5-9) is located along the central and eastern flanks of the San Rafael Swell, a prominent domed upwarp lying in Emery County and northern Wayne County, Utah. The Swell is a huge elongate asymmetric anticline whose northeast/southwest trending axis is about 110 km long. The northwest/southeast axis is about 50 km wide (Gilluly 1929). Being asymmetrical, the western flank of the swell has an average dip of only 5° to 20° while the eastern side dips more steeply from about 10° to 85° (Baker 1946).

The southwestern and eastern side of the Swell is marked by a high ridge of resistant sandstones, known as the San Rafael Reef, which rises abruptly above the San Rafael Desert. The eastern slope of this hogback feature merges with the desert surface while the western face forms a high, nearly vertical escarpment that rises nearly 600 m above the adjacent sloping surface in some portions of the Swell (Baker 1946). This barrier between the San Rafael Desert and the Swell can only be crossed in a few locations, such as Black Dragon Canyon and Temple Wash.

The study tract is located along the central and eastern flanks of the Swell, in an area known as Sinbad Country. Within this area, the terrain varies from extremely dissected tablelands with ridges of broken shaley sandstone, to fairly level valleys containing alluvial and eolian deposits. The dissected areas primarily occur along the eastern edge of the Swell, in areas such as Temple Mountain and Reds Canyon, where the bedding planes are steeply dipped, and along portions of the San Rafael River. In contrast, areas near the crest of the dome contain open, rolling terrain with broad valleys. The entire region is dotted with mesas and in places, is deeply dissected by ephemeral drainages. Relief in the study tract is approximately 1120 m, with elevation ranging from about 1280 m in the San Rafael River

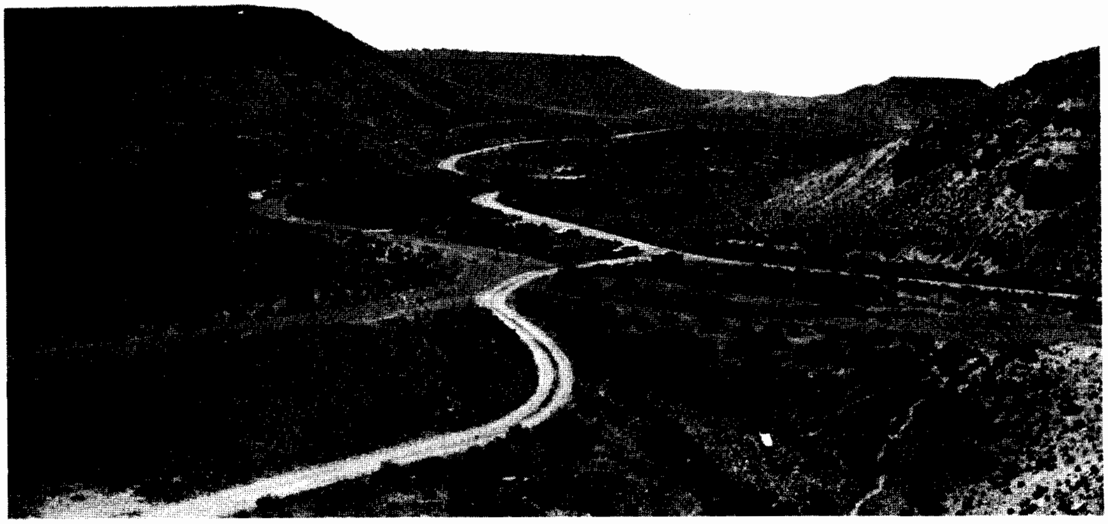

Figure 5. Little Ocean Draw in the vicinity of Tan Seep in the San Rafael Swell study tract. Several sites with subsurface deposits occur along the drainage in the sagebrush flats.

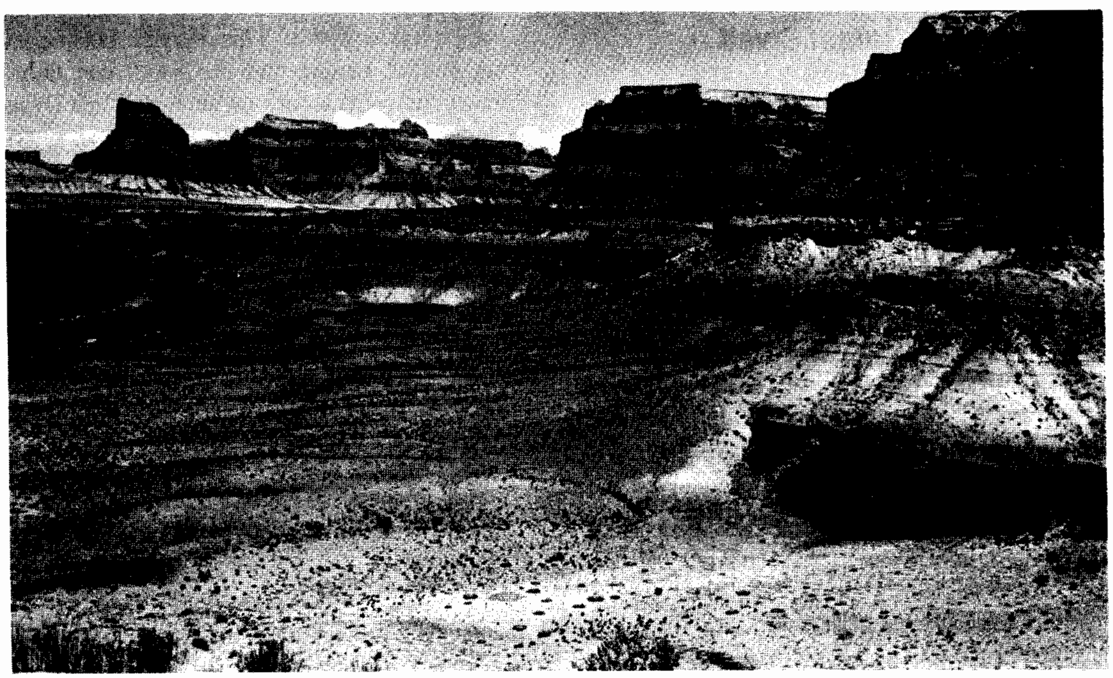

Figure 6. The San Rafael River valley showing the barren, dissected terrain above the narrow riparian zone along the river.

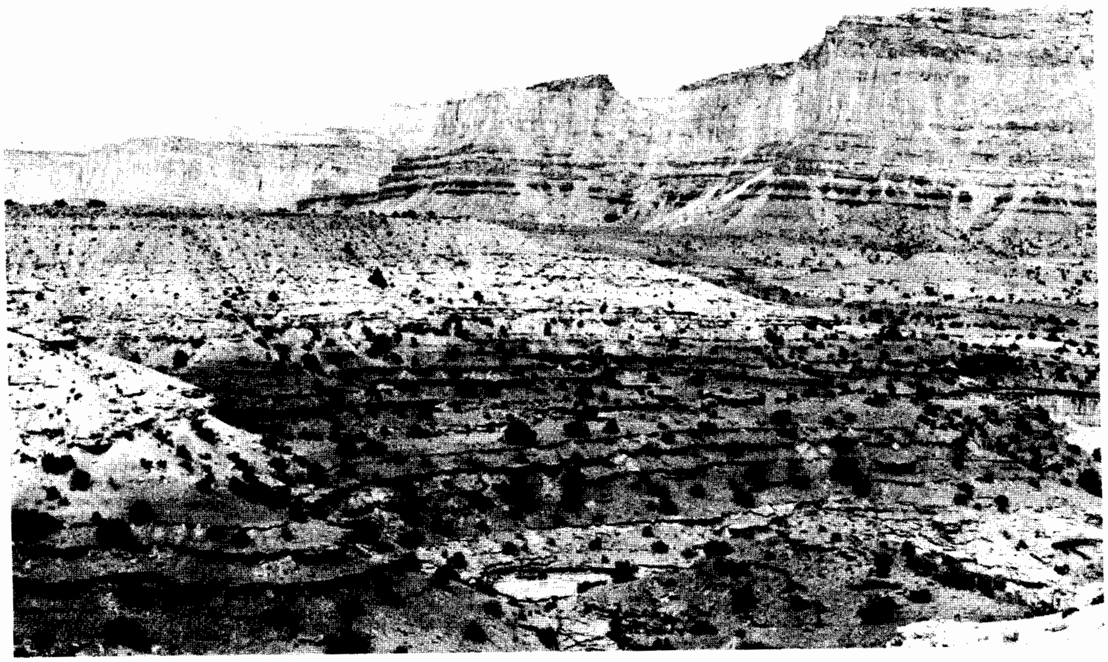

Figure 7. Typical example of eroding shaley sandstone of the Moenkopi Formation in the San Rafael Swell study tract.

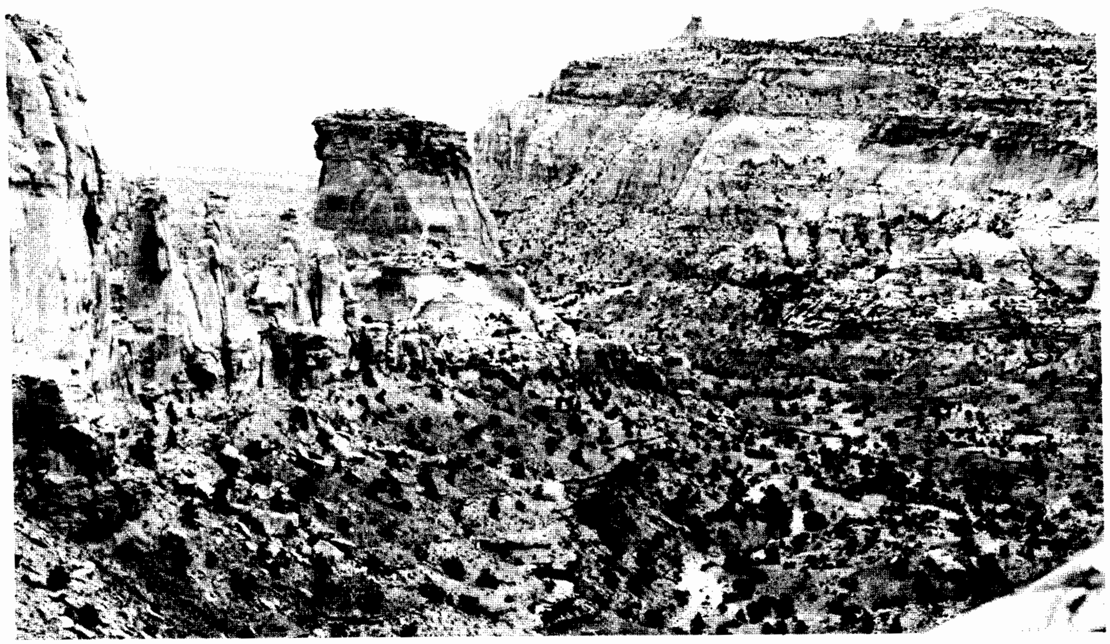

Figure 8. The Reds Canyon area in the San Rafael Swell study tract showing the Wingate cliffs and the Chinle Formation talus slopes.

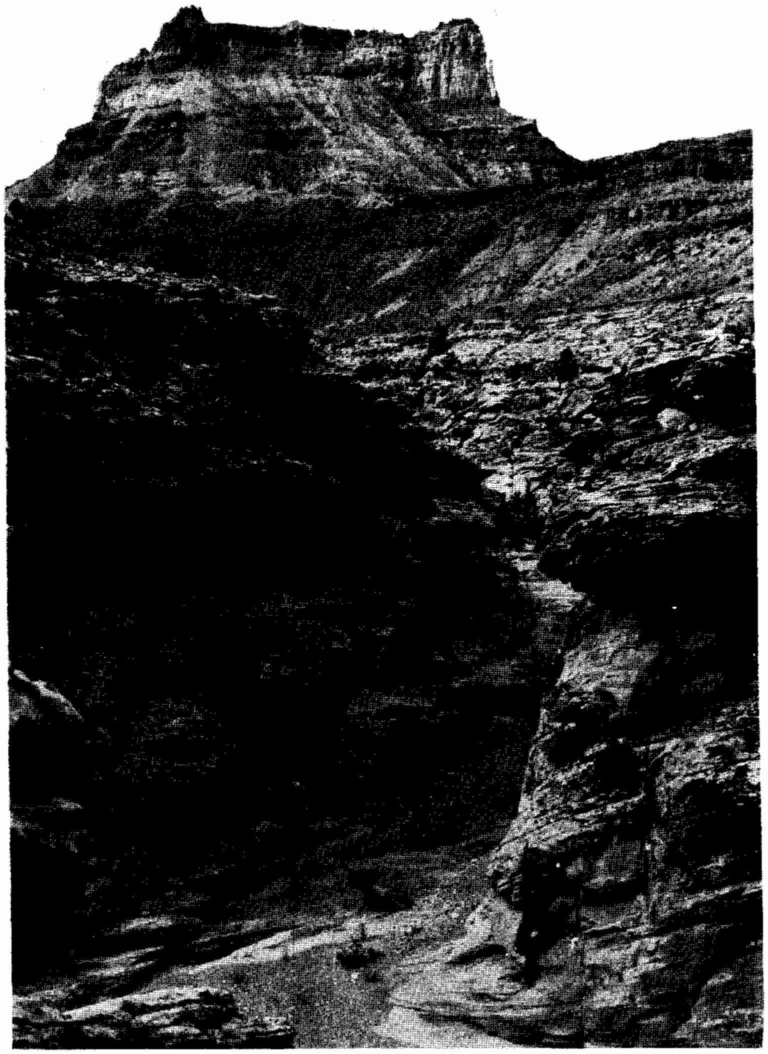

Figure 9. Temple Mountain and the canyon of Temple Wash in the San Rafael Swell study tract. Strata exposed in this area range from the Moenkopi through the Wingate formations.

canyon near Mexican Bend to over 2400 m on the San Rafael Knob at the apex of the upwarp.

The geologic strata exposed in the study tract range from Permian sandstones and limestones to the Jurassic Carmel sandstone of the San Rafael Group; progressively younger formations including the Upper Cretaceous Mancos Shale occur west of the study tract (Gilluly 1929). Much of the study tract consists of fairly flat benches of the Sinbad Limestone Member of the Moenkopi Formation and mesas of broken shales and mudstones of the upper Moenkopi Formation. These mesas are usually capped by the more resistant Shinarump Conglomerate. The higher mesas such as Temple Mountain and Window Blind Peak are capped by the Chinle Formation and the cliff-forming Wingate Formation. Additionally, many drainages have cut deep canyons through the Moenkopi exposing large expanses of Permian Kaibab Limestone. A few quadrats are located on the western side of the Swell in Link Flats, where the Navajo and Carmel sandstones are the predominant formations.

The San Rafael River, situated along the northern edge of the study tract, and the Muddy River, lying to the south, are the only perennial streams in the area. In addition to the perennial streams, water occurs at locations such as Tan Seep and Mexican Seep. Potholes or "tanks" eroded into the limestone bedrock of the drainages and in the sandstone on the mesa tops often contain water after rains.

The vegetation in the San Rafael study tract is primarily within the Shadscale Zone in the lower elevations, and the Pinyon-Juniper Zone in the higher elevations. The steep talus slopes and rough terrain are generally barren. In the dissected, shaley sandstone tablelands, the vegetation is fairly sparse with rabbitbrush, snakeweed, greasewood, shadscale, sagebrush, Mormon tea and a few grasses. The open, gently rolling country and the broad valleys are generally covered with various grasses and a few shrubs. At higher elevations, a sparse pinyon-juniper woodland extends into the open country. The sparse understory includes rabbitbrush, buffaloberry, mountain mahogany, sagebrush and snakeweed. Cottonwoods and thick stands of tamarix grow along the San Rafael River.

White Canyon

The White Canyon study tract (Figure 10) is situated on the western flank of the Monument Upwarp between the Grand Gulch Plateau and the Colorado River (Gregory 1938). This large upwarp has a steep eastern flank with dips exceeding 50^{o} at Comb Ridge. The gentle western side continues, with dips of only 0.5^{o} to 2.0^{o}, for about 50 to 80 km to the Colorado River and beyond (Gregory 1938). In the vicinity of the study tract, the western flank is dissected by White and Dark canyons, two major tributaries to the Colorado River.

Erosion by the White Canyon drainage has created a flat, broad outer canyon bordered on the south by massive and almost continuous high cliffs. To the north, it is bordered by broad areas of lowlands dotted with low mesas and ridges and such prominent buttes as Jacob's Chair and the Cheese Box. The modern White River and its tributaries have cut deep, sinuous inner canyons within the older outer canyon.

The study tract lies on the lowlands northeast of White Canyon between Long and Fortknocker canyons. Most of the study tract is made up of low mesas with steep talus slopes and rough, dissected tops. Also included are small portions of the adjacent flats and drainages surrounding the mesas and a portion of the high mesas south of White Canyon. In the vicinity of the study tract, elevation ranges from 2074 m at Jacob's Chair to about 1340 m in the inner White Canyon, although most of the area lies between 1525 and 1830 m.

The geologic strata exposed in the study tract include the Permian Cutler Formation, the Triassic Moenkopi, Shinarump and Chinle formations, and the sandstones of the Glen Canyon Group (Table 1). The low mesas making up most of the study tract consist of the Organ Rock Member and Moenkopi Formation, while the surrounding flats are Cedar Mesa Sandstone. The high mesa bordering White Canyon on the south contains strata ranging from the Moenkopi Formation through Navajo Sandstone. Recent surficial deposits such as sand dunes have formed between the drainages and at the base of some mesas.

The Colorado River lies just west of the project area and is easily accessible from White Canyon or through tributaries to Dark Canyon such as Lost Canyon. Water also occurs in seeps or springs in the canyons where Cedar Mesa Sandstone is exposed. A small seep in a tributary to Long Canyon was observed during the survey.

The vegetation of the White Canyon study tract consists of primarily the blackbrush community of the Shadscale Zone. Most of the flats above White Canyon and its tributaries contain blackbrush mixed with such shrubs as rabbitbrush, saltbush, Mormon tea and snakeweed.

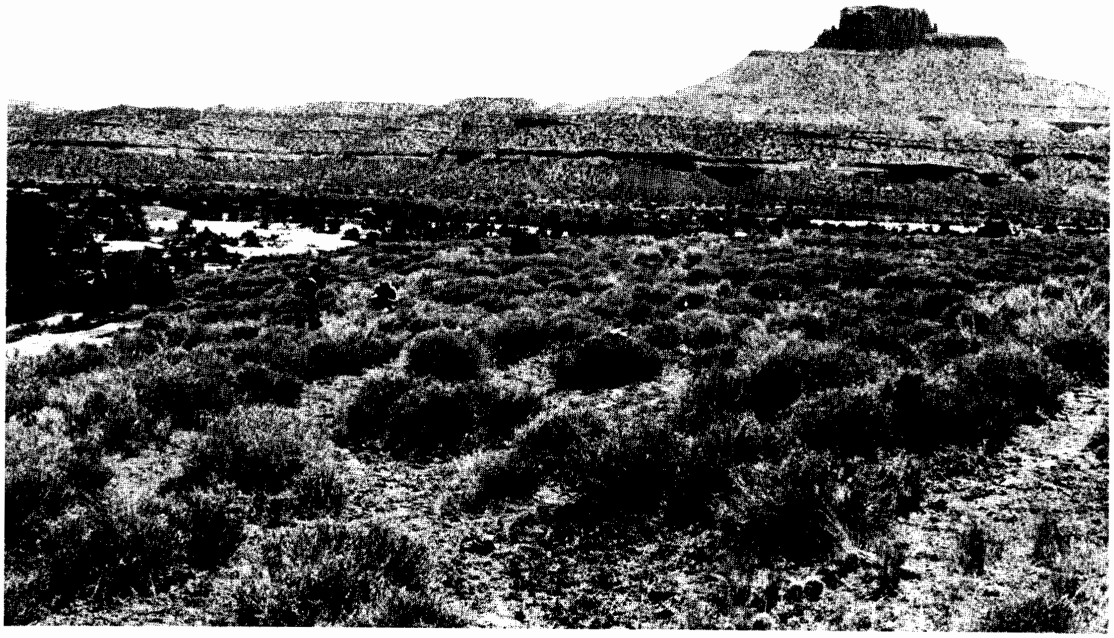

Figure 10. The blackbrush-covered flats adjacent to Long Canyon in the White Canyon study tract. The Wingate Formation pinnacle is Jacob's Chair.

In places, especially along drainages that head on the mesas, pinyon and juniper extend down into the blackbrush association. A pinyon-juniper woodland with a sagebrush understory covers the flats between the mesas and Dark and Lost canyons. Indian rice grass and various other grasses grow in the sandy areas.

Chapter 3

Culture History

The human habitation of Utah is thought to have begun as early as 12,000 years ago and to have continued intermittently until the present. The Paleoindian, Archaic, Formative and Post-Formative lifeways are all represented within the general project area. Cultural groups typifying these lifeways include the Paleoindian, Archaic, Anasazi, Fremont, Hopi, Southern Paiute, Ute and Navajo.

Euroamerican history within the general project area began in 1776 when Escalante and Dominguez passed through southern Utah while trying to establish an overland route between Spanish settlements in New Mexico and California. They were soon followed by trappers, traders and slavers and by the mid-1800s, Mormon pioneers and settlers and government-sponsored explorers. Recent activities in the area include grazing, mineral exploration, reclamation projects and recreation stimulated by the creation of national parks, recreation areas and monuments.

Paleoindian Period

The Paleoindian cultural tradition dates from about 12,000 to 8000 B.P. Evidence of this tradition is fairly scant in central and southern Utah and mainly consists of isolated artifacts assignable to this period on a typological basis (Hauck 1979a; 1979b; Schroedl 1976, 1977). For example, near the San Rafael Swell study tract, Tripp (1966, 1967) reports on two surface finds, a Clovis point near Emery and a Folsom point in the San Rafael Swell. A Folsom point was also found in the vicinity of Ferron, but subsequent excavations failed to produce other evidence of such early occupation (Gunnerson 1956).

In southeastern Utah, closer to the White Canyon study tract, a number of isolated Paleoindian points have been reported as surface finds (Hunt 1953; Hunt and Tanner 1960; Lindsay 1976; Pierson 1981; Sharrock and Keane 1962). Likewise, additional finds may also suggest limited Paleoindian presence near the Circle Cliffs study tract (Hauck 1979b; Schroedl 1976, 1977). To date, no stratified sites with unequivocal evidence of Paleoindian occupation have been reported in or near the project area.

Archaic Period

The succeeding Archaic period is thought to have lasted from at least 8000 B.P. until A.D.1/500 on the northern Colorado Plateau (Schroedl 1979:345). Following Steward's (1938) model of Shoshoni hunting and gathering groups, it is inferred that the Archaic peoples had a broad-based hunting and gathering economy dependent on a wide range of seasonally available plant and animal resources. It is also thought that they followed an annual round in response to changing resource availability, living in small, kin-related groups throughout most of the year. When resources were abundant in a localized area, the size of the local group may have increased considerably and the diet may have focused on only a few main staples.

In the late 1950s and early 1960s, the Desha, Moab, La Sal and Aneth complexes were established to describe Archaic assemblages in the general project area. The Desha Complex, now dated between 8750 and 6750 B.P. (Ambler 1984), was defined at Dust Devil and Sand Dune caves in the Navajo Mountain area south of the Colorado River (Lindsay et al. 1968). The Moab, La Sal (Hunt and Tanner 1960) and Aneth (Mohr and Sample 1959) complexes were identified on the basis of surface finds near Moab and Aneth, Utah, respectively.

More recent excavations at stratified cave and rockshelter sites—Sudden Shelter (Jennings et al. 1980) in central Utah and Cowboy Cave (Jennings 1980) in southern Utah—have greatly added to the previously limited understanding of the Archaic period in the general project area. Using the data from these excavations, Holmer (1978) analyzed changes in projectile point morphology through time and developed a point typology for the northern Colorado Plateau and eastern Great Basin. This typology, which is discussed in further detail in Chapters 5 and 6, was used to establish tentative dates and affiliations for many preceramic sites discovered during the Tar Sands survey.

In another study, Schroedl (1976) examined the distribution of radiocarbon dates, projectile points and other artifact types at Sudden Shelter, Cowboy Cave and a number of other sites, and postulated a sequence of cultural development, adaptation and population fluctuation for the Archaic period of the northern Colorado Plateau. His phases have the following names and time spans: Black Knoll, 8300 to 6200 B.P.; Castle Valley, 6200 to 4500 B.P.; Green River, 4500 to 3300 B.P.; and Dirty Devil, 3300 to 1500 B.P. Based on this work, Schroedl (1976:62) questioned the validity of the Desha complex but included it in his earliest phase, Black Knoll. Based on Ambler's (1984) re-excavation of Dust Devil Cave, he now views it as a distinct cultural entity, still assignable to the Black Knoll phase. Schroedl along with Berry (1975:76) discount any cultural or temporal assignments for the Moab and La Sal complexes because they are based on fortuitous surface associations that have never been identified in controlled stratigraphic excavations.

Excavated Archaic sites near the San Rafael Swell study tract include Sudden Shelter (Jennings et al. 1980), Cedar Siding Shelter (Martin et al. 1983), Joe's Valley Alcove (DeBloois 1979), Pint Size Shelter (Lindsay and Lund 1976) and Clyde's Cavern (Winter and Wylie 1974). Cowboy and Walters caves (Jennings 1980) are located north of the White Canyon study tract while Captain's Alcove (Tipps 1983), Dust Devil Cave (Ambler 1984) and Sand Dune Cave (Lindsay et al. 1968) are south and southeast of Circle Cliffs.

Although certain aspects of the Archaic lifeway have been fairly well documented through these excavations, most of this information is from cave, alcove or overhang sites. The more ubiquitous, small, open and often limited activity sites have been generally ignored, even though they surely comprise an important aspect of the overall settlement and subsistence system. The role of such sites in Archaic settlement and subsistence patterns is and will continue to be an important research topic on the northern Colorado Plateau.

Late Prehistoric Period

The Late Prehistoric period is characterized by more sedentary cultures, population growth and aggregation, a horticultural economy supplemented by undomesticated plant and animal foods, and technological innovations such as ceramic containers, adobe and masonry structures and water control devices. As used here, the Late Prehistoric period refers to the block of time between the introduction of pottery and the bow and arrow circa A.D. 250/500 and the advent of the Protohistoric period circa A.D. 1300. Two archeological cultures, the Fremont and the Anasazi, inhabited the project area during the Late Prehistoric period (Gunnerson 1957, 1969; Nickens 1982).

Circle Cliffs lies near the purported boundary between the Virgin and Kayenta Anasazi and the San Rafael Fremont. It has long been considered a transitional zone between these cultures (Aikens 1966b; Jennings 1966). In contrast, the San Rafael Swell tract is clearly within the geographical confines of the San Rafael variant of the Fremont culture (Madsen

1975a; Marwitt 1970). The White Canyon area has traditionally been included with the Mesa Verde Anasazi (Nickens 1982), though researchers are now finding increasing evidence of Kayenta Anasazi presence or influence (Hobler and Hobler 1978; Lucius 1979). Further confusing the Late Prehistoric period occupation in the White Canyon area are the Fremont style pictographs which are relatively common (Schaafsma 1971; Schroedl 1982).

Anasazi

The Anasazi tradition is thought to have emerged from local antecedents on the Colorado Plateau (Irwin-Williams 1973; Schroedl 1976) and can be subdivided into six chronological periods following the original Pecos classification (Kidder 1927): Basketmaker II and III, and Pueblo I through IV. Temporal spans assigned to these periods vary across the Anasazi area. Those proposed for southeastern Utah in general (Jennings 1966) and the Lower Glen Canyon area (Lindsay et al. 1968) in particular are presented in Table 2. Both sequences are primarily based on work conducted by the Upper Colorado River Basin Archeological Salvage Project (Glen Canyon Project) in the Glen Canyon area during the late 1950s and early 1960s.

Although only a few small surveys have been conducted in the immediate vicinity of the White Canyon study tract (Lucius 1979), generalizations about the Anasazi use of this area can be drawn from a number of projects that have been completed in surrounding localities. These include the Red Rock and Dark Canyon plateaus, Beef Basin, Elk Ridge, upper White Canyon, Cedar Mesa and Grand Gulch. Anasazi occupations near the Circle Cliffs tract must likewise be summarized from neighboring regions: the Kaiparowits Plateau, the Escalante Desert, the Waterpocket Fold and canyons in the Escalante drainage system. Work in all of these areas has shown that the occupation of southeastern Utah was not continuous, nor were populations evenly distributed throughout the Anasazi era. This research has also revealed changes in the distribution of Virgin, Kayenta and Mesa Verde attributes and influences through time, as well as interaction with the Fremont in certain areas.

Based on data collected by the Glen Canyon Project, Lipe (1967a) believes that the Red Rock Plateau, located southwest of White Canyon (and southeast of Circle Cliffs), was sparsely populated during Basketmaker II, and then essentially abandoned until Pueblo III when "sites were much more numerous and were less restricted in distribution than in the earlier . . . [Basketmaker II] phase" (Lipe 1970:114). Lipe recognizes two chronologically separate episodes of occupation during Pueblo III. The earlier Kletha Phase, dating between A.D. 1100 and 1150, is attributed to the Kayenta. The later Horsefly Hollow Phase dates from A.D. 1210 to 1260 and exhibits traits of both the Mesa Verde and Kayenta Anasazi. Although Lipe argues that there is little or no evidence of Pueblo II in this area, others who extend Pueblo II until A.D. 1150 (Lindsay et al. 1968) would probably categorize his Kletha Phase sites as late Pueblo II.

Table 2. Dates of Anasazi cultural periods in southeastern Utah.

Period	Jennings 1966	Lindsay et al. 1968
Basketmaker II	A.D. 1- 500	A.D. 1- 600
Basketmaker III	A.D. 450- 750	A.D. 600- 800
Pueblo I	A.D. 750- 900	A.D. 800-1000
Pueblo II	A.D. 850-1100	A.D. 1000-1150
Pueblo III	A.D. 1100-1300	A.D. 1150-1300
Pueblo IV	A.D. 1300-1700	A.D. 1300-1850

On the Dark Canyon Plateau, some 15 km northeast of the White Canyon study tract, Lipe (1967b) reports a sizable late Pueblo II/Pueblo III occupation, but only scanty evidence of earlier settlement. In a somewhat analogous situation, the nearby Beef Basin exhibited limited evidence of Basketmaker II and III, extensive evidence of Pueblo II/III, and little indication of Pueblo I (Rudy 1955; Thompson 1979). Although some Kayenta materials were found, all of the sites in both of these areas were ascribed to the Mesa Verde Anasazi.

In contrast to the Red Rock and Dark Canyon plateaus, Elk Ridge, a highland mesa some 35 km east of the White Canyon study tract evidently had a substantial Pueblo I occupation. Basketmaker II sites were relatively rare in relation to the total number of sites, although there was greater evidence of Basketmaker III. Pueblo II and III sites were relatively common (DeBloois 1975).

Some 35 km south of the White Canyon study tract, lie Cedar Mesa and Grand Gulch where Basketmaker II sites are abundant in both the canyon and mesa environment (Matson and Lipe 1975). Basketmaker III sites are less numerous on Cedar Mesa, although some were found on the Utah Highway 5 Project just north of this area (Dalley 1973; Wilson 1974). As in most of the other areas, evidence of Pueblo I and early Pueblo II is quite limited, whereas late Pueblo II and Pueblo III sites are much more common (Lipe and Matson 1971). Mesa Verde ceramic styles predominate in late Pueblo II and mid- to late Pueblo III. Kayenta pottery prevails in early Pueblo III (Haase 1983).

In the upper White Canyon drainage system, just 20 km south of the White Canyon study tract, Basketmaker II sites are relatively rare. Basketmaker III/Pueblo I sites are reportedly more common, but not unexpectedly, most of the sites are assigned to the Pueblo II/III time period (Hobler and Hobler 1978; Schroeder 1965). Hobler and Hobler (1978) note some difficulty in finding and identifying Basketmaker II sites and suggest that others may exist. It is also noteworthy that their Basketmaker III/Pueblo I designation does not include any sites that contain only Pueblo I characteristics. Rather they argue for the joint designation because they feel that the area may have been inhabited during the Pueblo I *temporal span*, but by a people possessing both Pueblo I and Basketmaker III traits. Both Mesa Verde and Kayenta pottery types are present in the upper White Canyon ceramic assemblage. The former predominates in collections from alcove sites. The latter prevails on open sites.

To summarize, the chronological evidence obtained from the foregoing localities shows that the area surrounding White Canyon was intermittently occupied from the Basketmaker II through Pueblo III periods by people possessing characteristics of both the Mesa Verde and Kayenta Anasazi. Pueblo I and early Pueblo II sites are relatively rare.

Basketmaker II sites in the general area are typified by slab-lined and jar-shaped storage cists, one-hand manos, basin metates, medium-sized corner- and side-notched dart points and a lack of pottery. On the Red Rock Plateau, they generally occur in canyons that contain abundant springs and natural overhangs, well-watered arable land, and that provide easy access to the nearby highlands (Lipe 1970). Basketmaker III is usually evidenced by open dwelling sites containing circular and rectangular slab-lined structures, pithouses and rectangular hearths. Artifact assemblages are characterized by arrow points, two-hand manos, trough metates, and in the upper White Canyon drainage system (Hobler and Hobler 1978; Schroeder 1965), crude gray pottery and painted pottery with Chapin/Lino Black-on-white design elements.

The small, scattered settlements that characterize the Pueblo II/III occupation in the general area often contain architectural features such as masonry and jacal rooms, slab-outlined hearths and rooms, masonry granaries, retaining walls, pithouses and possible kivas. Less common, but also present are two-story structures, check dams, towers, nonarchitectural sherd and lithic scatters and rock art panels (Schaafsma 1971; Schroedl 1982; Steward 1941).

In the upper reaches of White Canyon, Pueblo II/III open sites frequently occur on flat-topped ridges between canyons, with the largest sites being found at elevations of 1950 m in areas with deep soil. Rockshelter sites are common in canyons with deep deposits, and in alcoves close to the canyon floor. Sherd and lithic scatters are found in both the canyon and upland environments. On Cedar Mesa, late Pueblo II/early Pueblo III sites mainly occur on the mesa tops, while later sites are found in the canyons (Matson and Lipe 1975). On the Red Rock Plateau, late Pueblo II/early Pueblo III sites are situated in natural alcoves within wide, well-watered canyons containing large plots of arable alluvium. By late Pueblo III, narrower canyons with smaller, discontiguous plots of arable land were also inhabited (Lipe 1970).

A number of sites have been excavated near the White Canyon study tract. These sites are primarily located in Beef Basin (Rudy 1955), upper Glen Canyon (Lipe 1970) and near Natural Bridges National Monument (Dalley 1973; Schroeder 1965; Wilson 1974).

West of the Colorado River, closer to the Circle Cliffs study tract, the Anasazi occupation follows the same general pattern as described above except that there is little indication of Anasazi habitation prior to late Pueblo II, and good evidence of Fremont, Virgin Anasazi and Kayenta Anasazi materials. For example, sites on the Kaiparowits Plateau, south and southwest of Circle Cliffs, are attributed to the Virgin (Gunnerson 1959a) or Kayenta Anasazi (Fowler and Aikens 1963) and placed within the late Pueblo II/early Pueblo III time period (Aikens 1962). In the Escalante Planning Unit, which includes some of Circle Cliffs, roughly one-third of the sites are assigned to the Virgin/Kayenta Anasazi, all dating to the Pueblo II era (Hauck 1979b). Other researchers working in the southern section of the Escalante Planning Unit, however, believe that most of the sites are Fremont rather than Anasazi (Suhm 1959).

Pueblo II/III sites on the Kaiparowits Plateau are generally small and dispersed, and rarely contain evidence of more than four rooms. Ridges and other elevated situations overlooking draws and sage flats are the favored site locations, though rockshelters are also utilized (Aikens 1962; Gunnerson 1959a). In summary, the general Circle Cliffs area witnessed its only major Anasazi occupation in late Pueblo II/early Pueblo, presumably as part of the well-known Pueblo II/III expansion. This area reportedly shows influence and interaction among the Virgin and Kayenta Anasazi and the Fremont.

Excavated sites near Circle Cliffs are chiefly located on the Kaiparowits Plateau (Fowler and Aikens 1963) and in side canyons of the Escalante drainage system (Gunnerson 1959b). One of the excavated sites near Circle Cliffs is Coombs Village, a large site that has often been characterized as the northern outpost of the Kayenta Anasazi. It contains over 75 storage and living structures including both pit dwellings, and masonry and jacal surface rooms. The ceramic assemblage is primarily Kayenta, though Fremont materials are also present. Like other Anasazi sites in the area, it is dated to A.D. 1100 (Lister and Lister 1961) or later (Jennings 1966:55-56), placing it in the Pueblo II/III time period.

Fremont

In the early twentieth century, various researchers noted a similarity between sites in central Utah and those in southwestern Colorado and northeastern Arizona. It was not until 1931, however, that archeologists recognized that the sites represented two cultural groups, the Anasazi and the Fremont (Morss 1931). Since that time, Steward (1933, 1940) and others have attempted to clarify the relationship between these cultural groups. The Fremont are now generally differentiated from more southerly Pueblo groups by their pottery, anthropomorphic clay figurines, moccasins and half rod-and-bundle basketry. Although they were horticulturalists like their Pueblo neighbors, they are thought to have had a less sedentary lifestyle and been more dependent on undomesticated food resources.

Once the Fremont were recognized as a separate cultural tradition, disagreements arose concerning their origin, disappearance and internal variation. In the 1950s, researchers postulated that the Fremont developed in situ from an Archaic substratum (Rudy 1953; Wormington 1955). This theory was questioned in the 1960s when it was hypothesized that the Fremont came from the Plains (Aikens 1966a) or that they developed from the Virgin Branch Anasazi (Gunnerson 1969). Although most discount the Plains and Virgin Branch hypotheses, researchers continue the debate whether or not the Fremont developed in situ from an Archaic culture (Aikens 1970; Jennings 1978; Madsen and Berry 1975; Schroedl 1976).

By the late 1960s and early 1970s, the focus of Fremont research shifted to identifying the differences and similarities between Fremont sites throughout the state of Utah. Using data from scattered excavation and survey projects, Marwitt (1970) examined variation in ceramic and architectural characteristics and identified five Fremont variants: Great Salt Lake, Uinta, Parowan, Sevier and San Rafael. His division has been supported by some (Lohse 1980), but criticized by others (Madsen and Lindsay 1977).

Madsen (1979:719), for example, has recently argued that ". . . the Fremont entity cannot be explicitly defined and, therefore, probably does not exist . . ." He argues instead the existence of two and possibly three separate cultural groups, linked by only a few common traits. According to Madsen (1979:720), the Fremont culture is located on the Colorado Plateau and is defined as ". . . an agriculturally dependent group that bears a strong resemblance to the Basketmaker Anasazi . . ." The second group, the Sevier culture, is situated in the Great Basin and has a marsh-based economy supplemented by agricultural crops. He also proposes a third group, an unnamed variant in the vicinity of the Great Salt Lake and Uinta Mountains of northern Utah. While many Fremont specialists disagree with Madsen's statement regarding the nonexistence of the Fremont as a cultural entity, they recognize that Fremont settlement and subsistence patterns differ between the Colorado Plateau (Marwitt's Uinta and San Rafael variants) and the Great Basin (Marwitt's Parowan, Sevier and Great Salt Lake variants) (Adovasio 1979; Aikens 1979; Lohse 1980; Marwitt 1979).

The San Rafael Swell study tract lies within the geographical area designated as the San Rafael Fremont, while the Circle Cliffs tract lies near the presumed boundary between the San Rafael Fremont and the Virgin and Kayenta Anasazi (cf. Marwitt 1970). The San Rafael Fremont are thought to have lived between A.D. 750 and 1240. Their sites are generally small with no more than 12 rooms used at a particular time. Architectural features include circular, stone-lined pit dwellings, coursed wet- and dry-laid masonry, adobe structures and slab-paved firepits with molded clay rims. Habitation sites are commonly located on ridges or high areas overlooking dependable water sources and arable alluvial soils. Caves and overhangs were also used for storage and habitation. Emery Gray is the dominant pottery type although sparse occurrences of both Mesa Verde and Kayenta Anasazi pottery are also reported.

The San Rafael Fremont was originally defined on the basis of only a few excavated sites in Nine Mile Canyon (Gillin 1955) northeast of the San Rafael Swell tract, a few others along the Fremont River northeast of Circle Cliffs (Morss 1931) and the Turner-Look site, west of the San Rafael Swell (Wormington 1955). Since that time, a number of San Rafael Fremont sites have been excavated, greatly enhancing our knowledge of this variant. Those excavated near the San Rafael Swell study tract include Windy Ridge, Power Pole Knoll and Crescent Ridge (Madsen 1975a), Innocent's Ridge (Schroedl and Hogan 1975), Clyde's Cavern (Winter and Wylie 1974) and Pint Size Shelter (Lindsay and Lund 1976). Based on information obtained during these excavations, several of Marwitt's Sevier variant sites—Old Woman, Poplar Knob and Snake Rock—have been reassigned to the San Rafael Fremont (Schroedl and Hogan 1975). These three sites are located just west of the San Rafael Swell study tract.

The cultural affiliation of Late Prehistoric sites near the southern end of the San Rafael Swell study tract and farther south toward Circle Cliffs is poorly understood. Sites in this area often contain both Fremont and Anasazi attributes. Madsen (1982), for example, recovered Fremont moccasins, a Kayenta bowl and Bull Creek projectile points from a single grave at Ticaboo Town. He questions the validity of assigning such sites to a particular cultural group and criticizes Jennings and Sammons-Lohse (1981) for assigning the nearby Bull Creek sites to the Fremont. Madsen (1982:25) goes on to point out that several of the Bull Creek sites had "Anasazi-style" architecture and mainly Anasazi pottery, yet they were "blithely" assigned to the San Rafael Fremont. Similar problems with differentiating cultural affiliation can be identified at Harris Wash (Fowler 1963), the Kaiparowits Plateau (Fowler and Aikens 1963) and the Escalante Desert (Hauck 1979b; Suhm 1959) and drainage system (Gunnerson 1959b), all located in the vicinity of Circle Cliffs. With the possibility of mixed traits in mind, it is worth noting that other San Rafael Fremont sites are reported along the Waterpocket Fold (Kay 1973; Lister 1959), in the Cave Flats/Tarantula Mesa area (Kearns 1982) and in the Henry Mountain Planning Unit (Hauck 1979a), all located near Circle Cliffs.

The disappearance of the Fremont culture and occupation of their area by Numic-speaking groups is one of the most widely debated topics in Fremont research today. This controversy has revolved around three main issues: whether the Numic speakers replaced, displaced or developed from the Fremont (Madsen 1975b). In the early 1960s, Gunnerson (1962) was one of the first to take the latter position, that the Numic groups derived from the Fremont. A few years later, Aikens (1966a) suggested that the Fremont moved onto the Plains and became Dismal River Apache. More recently, researchers have suggested that deteriorating climatic conditions caused the agriculturally dependent Fremont to abandon their traditional range prior to the arrival of the Numic peoples (Aikens and Witherspoon 1982; Jennings 1978). Madsen (1975b), on the other hand, has shown that Fremont and Numic-speaking groups were contemporaneous at a number of sites in the eastern Great Basin and has used these data to argue that the Numic groups were partially responsible for the demise of the Fremont. Their disappearance continues to be a significant question in central Utah archeology.

Protohistoric Period

The Protohistoric period in the project area is primarily represented by the Numic-speaking Ute and Paiute groups who are thought to have inhabited the area from A.D. 1250/1300 (or earlier [Madsen 1975b]) until historic times (Euler 1964, 1966). As noted above, the origin of these groups has been an issue of considerable controversy over the years (Aikens and Witherspoon 1982; Bettinger and Baumhoff 1982; Euler 1964; Gunnerson 1962; Lamb 1958; Madsen 1975b). The most widely accepted theory, however, is that they began to enter the Great Basin between A.D. 900 and 1000 from a linguistically diverse core area located somewhere in the vicinity of Death Valley (Lamb 1958).

Numic-speaking groups are poorly known archeologically (Euler 1964; Sweeney and Euler 1963), but are relatively well documented in the records of ethnographers (Kelly 1964) and ethnohistorians (Euler 1966). Like their Archaic predecessors, these groups had a hunting and gathering economy and followed an annual seasonal round. But unlike the Archaic people, they supplemented their diet with sporadic corn horticulture.

Archeologically, Numic sites are recognized by Desert Side-notched projectile points and thick, crude, brownware pottery (Jennings 1978). Given this relative paucity of diagnostic materials, it is not surprising that few sites in the general project area can be unequivocally assigned to Paiute and Ute groups. One site with a Protohistoric period date was recently investigated near the San Rafael Swell; it consisted of a cache found in an overhang (Benson 1982).

Black-on-yellow Pueblo IV Hopi pottery occurs in small quantities throughout the southern portion of the project area (Hauck 1979b; Lipe 1970; Suhm 1959). Lipe (1970) and Suhm (1959) attribute these materials to limited visits by Hopi parties for specific tasks such as hunting or trading. Lucius (1983) believes they are trade wares used by Numic-speakers after A.D. 1400.

The Navajo, a pastoral group presently residing in the Four Corners area, are thought to have arrived in the Southwest by approximately A.D. 1500 and in southeastern Utah by A.D. 1700 (Nickens 1982). Though their traditional range is somewhat farther south, their presence in the White Canyon area has been documented both ethnographically (cf. Hobler and Hobler

1978) and archeologically (Haase 1983; Hobler and Hobler 1978; Schroeder 1964).

Historic Period

by Kenneth W. Russell

Early Explorers, Trappers and Traders, 1776 to 1860

The earliest authenticated Euroamerican entry into the regions surrounding the project area occurred during the Dominguez-Escalante expedition in 1776. Subsequent Spanish trading expeditions from New Mexico to the Ute country, such as the Mauricio Arze and Lagos Garcia expedition to Utah Lake and the Sevier Valley in 1813, eventually led to the establishment of the final route of the Old Spanish Trail (Figure 11). Other documented Euroamerican explorers include the Antonio Armijo party, which crossed the Colorado River at the Crossing of the Fathers below Ute Ford in 1829, and Denis Julien, a French trapper and fur trader from St. Louis who carved his name in Cataract and Labyrinth canyons in 1836. As early as 1824, Americans from Missouri were trapping and trading with the Indians along the Colorado and Green rivers, and Kit Carson is said to have spent a winter trapping in the La Sal Mountains and the area near the mouth of the Green River. Wolfskill and Ewing Young worked the San Juan and other tributaries of the Colorado, and Etienne Provost trapped along the Colorado and Green rivers (Brooks 1977:45; Crampton 1959:1-2, 1962:45, 1979; Daughters of Utah Pioneers 1957:21, 1977:3; Kelly 1933a, 1933b; Mauerman 1967:4-6; Peterson 1975:5-11; Rauch 1981:38).

Prior to any permanent Euroamerican settlement in Utah, the Old Spanish Trail was the principal thoroughfare through the region for Indians, trappers, traders and slavers. New Mexican traders and horsemounted Ute groups used this route to move Paiute women and children captured in the Sevier River Valley to Santa Fe and Los Angeles, the two terminals of the trail. Such activities were increasingly discouraged after the arrival of the Mormons in Utah in 1847. In 1852, the Territorial legislature outlawed all slaving activities, and in 1853, Brigham Young took further action against slavers by sending out a small detachment of men to arrest all individuals involved in such activities. Even so, slaving continued along the Old Spanish Trail until at least 1860 (Creer 1958b:6-9; Hill 1930:20-23; Snow 1929; Weathers and Rauch 1982:25).

Initial Mormon Colonization and the Indian Wars, 1847 to 1870

It was the arrival of the Mormons in Utah in 1847 that led to the first permanent colonization of Utah by Euroamericans. Within a decade of their arrival, approximately 100 inner-cordon settlements had been founded from Bear Lake to the Virgin River, primarily along the Wasatch Front. Several conflicts occurred between Indians and Mormon settlers during this period of colonization including the Walker War from 1853 to 1854, the Black Hawk War (1865 to 1868)—involving the Utes of central Utah and the Paiutes of southern Utah—and the Navajo raids on the southern settlements prior to 1870. It was also between 1866 and 1869 that the Utah territorial militia, in the pursuit of various Indian groups, effectively explored many of the uncolonized regions north of the Colorado River which would soon be the object of further settlement (Crampton 1959:8-9; Creer 1958a:1-2; Emery Historical Society 1981:14; Mauerman 1967:31-33; Ogden 1898:594; Peterson 1975:11-15).

Federal Government Exploration, 1848 to 1879

In 1848, after the vast western territories were ceded to the United States by Mexico and gold was discovered in California, the federal administration authorized exploration to locate routes for mail transport and a transcontinental railroad. To this end, Kit Carson traversed Castle Valley in 1848, as did the expedition of Lieutenant John W. Gunnison in 1853. Gunnison's party, entitled the "Central Pacific Railroad Surveying Expedition," crossed the ford at Green River, where they left the Old Spanish Trail in an attempt to situate the

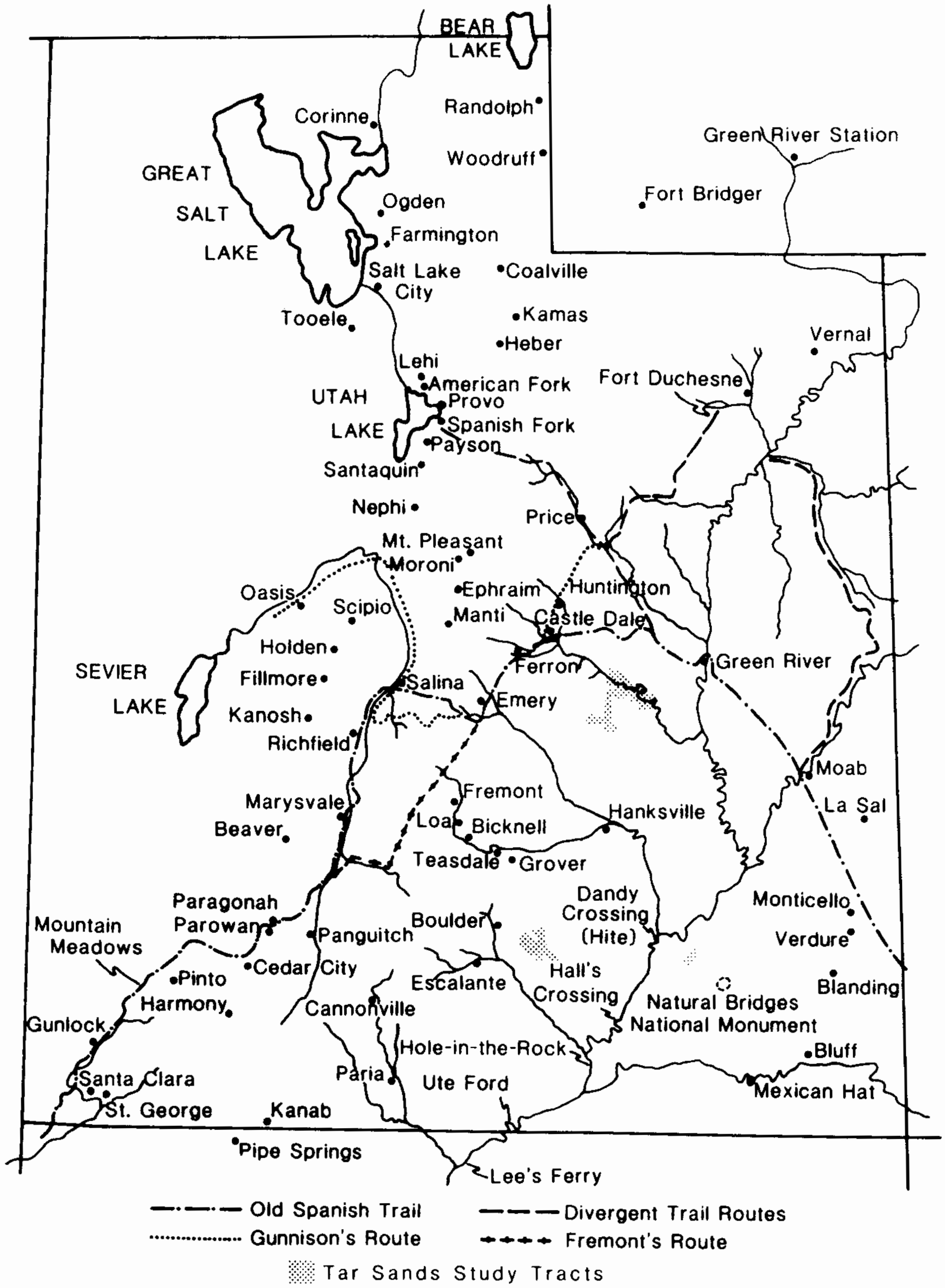

Figure 11. Map of important historic locations in Utah.

railroad line around the northern end of the San Rafael Swell (Crampton 1979:373; Emery Historical Society 1981:11; Rauch 1981:39; Weathers and Rauch 1982:25).

Although John C. Fremont, John N. Macomb and others explored parts of Utah and the Four Corners area, it is the work of John Wesley Powell that dominated further federal explorations in the general project area, and it was Powell's surveys that provided the first accurate and comprehensive description of the Colorado River system in Utah (Crampton 1959:5-7; Creer 1958b:20-24; Larson and Peterson 1978:375-378).

Advance of Euroamerican Settlements and the Railroad, 1873 to 1884

The primary Euroamerican settlements surrounding the study tracts were generally the result of Mormon settlers from older adjacent communities in Utah and the advance of both miners and cattlemen based primarily in southwestern Colorado. In the Castle Valley region near the San Rafael Swell study tract, initial Mormon settlement was inspired by the U.S. government Homestead Act of 1862. Unlike earlier settlement patterns in Utah, ranchers rather than farmers were first to settle the valley. Cattle and sheep from Mormon communities in the Sanpete Valley were brought into the region for winter grazing via Cottonwood Canyon. As a result of their success, Brigham Young issued a colonization plea in 1877 and settlements were soon established at Ferron, Castle Dale, Huntington and Price. As elsewhere, the new colonists began farming immediately, although such efforts remained on a subsistence level until quite recently, due primarily to technological and resource limitations in constructing dams, reservoirs and canals, increasing salinization of soils as a result of irrigation, and extensive erosion due to overgrazing (Crampton 1959:10; Emery County Historical Society 1981:199-200; Larson and Peterson 1978:378; Mauerman 1967:42-51; Powell 1979:55-60, 86-87; Weathers and Rauch 1982:25-27).

In 1881, construction was begun on the Utah section of the Denver and Rio Grande Western Railroad line. The line was initially graded from the newly founded community of Green River, north around the San Rafael Swell to Buckhorn Flat, and would have traversed Castle Valley prior to joining the north/south railroad line from Salt Lake City near Salina. The railroad abandoned this route in 1882 because of concern over robbery, as well as the market potential of the then developing coal industry in the Price area (Jorgensen 1955:82; Larson and Peterson 1978:383; Ogden 1898:601; Powell 1979:125-126; Rauch 1981:42-43; Weathers and Rauch 1982:28).

Throughout the 1870s and early 1880s, a number of new Mormon communities were also established along the southeastern base of the Southern High Plateaus closer to the Circle Cliffs study tract. In 1875, settlers from Panguitch founded the town of Escalante at the upper end of the Escalante River. Starting in 1879, stockmen from Escalante began to range cattle into the Boulder Valley. The small community of Boulder soon developed around such stockherding activities, since the area was unsuited for farming and contained no valuable mineral deposits (Crampton 1959:10-11; Creer 1958a:5-14; Daughters of Utah Pioneers 1949:93-148). Between 1875 and 1884, the Mormon communities of Bicknell, Loa, Teasdale, Fremont, Torrey and Grover were also established along the Fremont River (Daughters of Utah Pioneers 1977:177-272). The economic viability of these communities was directly tied to a dual economy based upon the exploitation of limited agricultural acreage and the grazing of animals (primarily cattle) across extensive desert rangelands.

It was the potential for grazing opportunities that led to the first permanent Euroamerican settlements southeast of the Colorado River in the vicinity of the White Canyon study tract. Throughout the 1870s, numerous non-Mormon Colorado cattlemen pastured their herds in the Abajo Mountains during the summer while ranging them in the grass and sage-covered plateaus of eastern Utah during the winter (Crampton 1959:12; Daughters of Utah Pioneers 1957:22-23; Larson and Peterson 1978:378-380; Peterson 1975:30-33, 40, 64). The Mormon Church became concerned that outsiders would take over the area:

> Fearful that outsiders would monopolize the San Juan country and anxious to cultivate good relations with the Indians, the Mormon Church leadership turned in 1879 to the time-proven device of the colonizing

> mission; settlers were called from Iron County and nearby parts of southern Utah [Larson and Peterson 1978:379].

In November of 1879, a colonizing expedition of about 230 men, women and children, drawn from Cedar City, Parowan, Paragonah, Harmony, Holden, Beaver and various other communities, headed down the Escalante River with 82 wagons and 1,000 head of cattle. At Forty-Mile Spring, it was discovered that they would have to pass through a fault-crack in a 50-ft cliff too narrow for the passage of wagons. They widened the crack by blasting, creating Hole-in-the-Rock, and succeeded in building a road down to the Colorado River, a 1,800-ft drop in only 0.75 mile. The "San Juan Mission" eventually reached the San Juan River on April 5-6, 1880, and camped a few miles below the mouth of Recapture Creek where they began to establish the town of Bluff (Crampton 1959:12-13, 1962:1-4; Daughters of Utah Pioneers 1957:39-58; Larson and Peterson 1978:379-380; Peterson 1975:42-44; Woodbury 1944:183).

Communication between the Bluff colony and the northern Mormon settlements was accomplished through Hole-in-the-Rock, and later, Hall's Crossing. The western approach to Hall's Crossing ran through the center of the Circle Cliffs study tract. This route left the Hole-in-the-Rock trail 10 miles south of Escalante at Harris Wash, which it followed to the Escalante River. The trail ascended Silver Falls Creek and travelled north along the western slopes of Wagon Box Mesa. Just south of Studhorse Peaks at the northern end of the study tract, the trail turned east, descending the Waterpocket Fold through Muley Twist Canyon and Burr Canyon to Hall's Creek, which it followed south to the crossing. It is highly probable that this route followed the lines of earlier Indian trails through this area. The Circle Cliffs trail continued to be used by livestockmen who ranged their cattle in the region (Crampton 1959:11, 1962:5-10, 50-51; Daughters of Utah Pioneers 1957:78; Larson and Peterson 1978:380).

Expansion of Livestock Interests and the Outlaw Trail, 1880 to 1918

Potential for high profits accounts for the western cattle boom during the 1880s. Southeastern Utah, with good ranges and its proximity to both western and eastern markets, soon attracted outside livestock interests in the form of big companies from Colorado and Texas. In the 1880s, many of the small operators were pushed out by such interests as the L. C. Cattle Company and the Kansas and New Mexico Land and Cattle Company, which acquired several of the Abajo Mountain holdings and became the largest cattle company in Utah and western Colorado. By 1885, big cattle companies controlled most of southeastern Utah with the exception of regions south and west of the Abajo Mountains, tenuously held by the Mormon community at Bluff. Here, attempts to establish a typical Mormon farming village failed, and only the shift from farm village to cooperative livestock production under Francis A. Hammond in 1886 prevented the total collapse of the settlement (Crampton 1959:27-28; Larson and Peterson 1978:380-382; Peterson 1975:50-51, 84-93).

While conflicts between Indians and Euroamericans diminished in the northern regions of the study area after the retirement of Black Hawk to the Uintah Reservation in 1867, several conflicts with Ute, Paiute and Navajo groups occurred after this period in southeastern Utah. Cowboys on the south slopes of the Abajo Mountains shot a Ute during an argument over a horse. A general insurgence by local Indians subsequently occurred. A cavalry detachment from Fort Lewis, Colorado, began tracking the Indians with the aid of local cowboys, following them west over Elk Ridge, past the Bears Ears, and around the south bend of White Canyon. The Indians exhausted the water holes along the way, and when the cavalry overtook the fleeing Indians in Piute Pass, the detachment's situation was becoming desperate. The Indians effectively commanded this narrow pass in the otherwise impassable mesa which forms the southern and western boundary of the White Canyon drainage and study tract. A local cowboy and a government scout were shot half way up the trail to the pass. Two months later, a prospector recovered and buried the bodies. The State Road Commission has since installed a monument at the grave site at Soldier's Crossing (Crampton 1959:13; Daughters of Utah Pioneers 1957:234-244; Peterson 1975:65-77), just south of the White Canyon study tract.

With large numbers of cattle and horses being ranged in this region of Utah, rustling and pilfering became quite common. Between 1883 and the turn of the century, the area known as Robbers Roost in the rough and nearly inaccessible country west of the junction of the Green and Colorado rivers was a haven for the individuals involved in such activities. After the Castle Gate holdup in 1897, Robbers Roost became the hideout of George LeRoy Parker, known as Butch Cassidy, and his outlaw associates, known as the Wild Bunch. Cassidy and associates made good their escape by riding south past Price, then down Buckhorn Wash to the San Rafael River. From here, they left the San Rafael Swell by way of Black Dragon Canyon, followed the San Rafael River to the Green, and then headed south to Robbers Roost. Their route through the San Rafael Swell via Buckhorn Wash, Cottonwood Wash and Black Dragon Canyon lies within the San Rafael Swell study tract and appears to follow the line of an earlier Indian trail. Although the principal routes south from Robbers Roost across the Colorado River followed stock trails to either Hall's Crossing or Lee's Ferry, the trail south from Hanksville through Trachyte Canyon to Dandy Crossing at Hite and thence up White Canyon was also quite popular. This latter route also appears to follow the line of an earlier Indian trail (Crampton 1959:28, 1962:42; Kelly 1959:7, 133-158).

Mineral Exploration and Mining, 1880 to World War II

Early coal production in what was initially Emery County and later Carbon County involved an extension of earlier mining activities from Sanpete County. The Pleasant Valley Coal Company was organized in 1876 and soon became the territory's largest producer. With the completion of the Denver and Rio Grande Western (D and RGW) line from Denver to Salt Lake City via Price Canyon in 1883, the Price area experienced rapid mining development under the Utah Fuel Company, a D and RGW subsidiary. By the turn of the century, the Emery-Carbon area had become the coal center of the West. The shift from farming to mining caused the residents of Price and the coal mining camps to petition for a separation from Emery County in 1894. The name "Carbon" County symbolized the passing of this region from its frontier stage into its mining future (Larson and Peterson 1978:383; Powell 1979:11-12).

At the southern end of the study area, early mineral exploration and mining were stimulated by the search for gold and silver rather than coal. Between 1880 and 1900, prospectors thoroughly explored the canyons and plateaus of southeastern Utah as well as the Carrizo, Abajo, La Sal and Henry mountains. Cass Hite discovered placer gold in the Colorado River gravels near Dandy Crossing (which he had named). Over the next seven years, a mild gold rush brought several hundred miners into the region (Crampton 1959:16-29).

In 1891, the first oil well in Utah was drilled near Green River, although it was not until World War II that any commercial producers were discovered. Sporadic drilling for oil prior to 1922 was generally shallow, after which time the expansion of the automobile industry led to a more complete exploration of oil-bearing horizons and structures. From 1909 to 1911, drilling was conducted around Bluff and Mexican Hat. None of these wells ever reached commercial output. There was little activity in the San Juan oil field from 1911 until the field was revived in 1920. From 1920 to 1930, wells were drilled in Monument Valley, Elk Ridge, Beef Basin, Dark Canyon, Grand Gulch Plateau, the Colorado River below Moab and Robbers Roost, as well as in Circle Cliffs and in the San Rafael Swell (Crampton 1959:62-63, 1962:30-31; Daughters of Utah Pioneers 1957:273-275).

Copper deposits also stimulated prospecting in and around the study tracts. Copper ores were found in association with the gold and silver ores of the Henry, La Sal and Abajo mountains, although deposits in the "red beds" were also found in the San Rafael Swell and on Miners Mountain near Capitol Reef. During the speculative boom in copper prices from 1905 to 1907, the deposits along the base of the mesa on the south side of White Canyon were developed. Various mines were worked in this vicinity intermittently until World War I, since few deposits could be worked profitably once the price of copper had stabilized after 1907 (Crampton 1959:60-61; Daughters of Utah Pioneers 1957:270).

Radioactive ore exploitation began with an expanding market for radium stimulated by scientific developments in the use of luminous materials and advances in medical research. Radioactive ore was first discovered in 1888 near Bedrock, Colorado. In 1893, prospectors found a yellow mineral (later identified as carnotite, a radioactive ore) in the Temple Mountain area near the southern end of the San Rafael Swell study tract. Mining of these deposits for uranium, radium and possibly vanadium began by at least 1914 and continued into the 1920s (Hawley et al. 1965). The total output of these operations is unknown (Johnson 1957). Following World War I, the deposits were intermittently exploited until 1948 when production rapidly increased, causing the Temple Mountain area to become one of the major uranium producers on the Colorado Plateau. Stimulated by the Atomic Energy Commission's purchase and exploratory program for uranium, other mines were opened in the early 1950s, including the Lucky Strike and Vernon Picks Delta.

In 1949, near the White Canyon study tract, a reduction mill was built through government support to process and treat the copper-type uranium ore of the Happy Jack Mine as well as uranium ores from neighboring Red Canyon. With the Happy Jack Mine being one of the richest uranium mines on the Colorado Plateau, a small settlement soon developed at the mouth of White Canyon near the mill (Bruyn 1955:102-103, 117; Crampton 1959:61-62; Daughters of Utah Pioneers 1949:152-154, 1957:271-272; Johnson 1957:39-40).

Reclamation and Recreation, 1908 to the Present

Government recognition of a need for a wider reclamation of the arid public domain is apparent in the Desert Land Act of 1877, designed to encourage individual reclamation projects, and the Carey Act of 1894, which provided for cessions of public lands up to 1,000,000 acres each to either states or territories which caused such lands to be irrigated, reclaimed and subsequently occupied. Federal financial participation in reclamation projects was subsequently initiated with the Newlands Act (or Reclamation Act) of 1902, to be funded by receipts from the sale of public lands in the 16 states and territories of the arid region. In 1925, E. C. LaRue, the hydraulic engineer of the Geological Survey, completed a preliminary comprehensive plan for the development of the Colorado River below the mouth of the Green River to provide for flood control, water storage for irrigation and power development. In 1922 the seven Colorado River basin states organized the Colorado River Commission with Herbert Hoover as chairman, and in 1923, the Colorado River Compact was ratified by all of the Commission states except Arizona (which eventually signed in 1944). Having removed the difficulties over prior rights, the compact established a base for coordinated reclamation efforts between the compact states. Federal legislation subsequently authorized the construction of major multi-purpose projects, including the Boulder Canyon Project Act of 1928 and the Colorado River Storage Act of 1956, which resulted in the construction of the Glen Canyon dam. In the 1930s, the Taylor Grazing Act was enacted to reclaim overgrazed public lands (Crampton 1959:65-73).

The recreational development of the study area was initially stimulated in 1904, when the September issue of *National Geographic Magazine* and the August issue of *Century Magazine* brought the area of Natural Bridges to the public's attention. An illustration of the bridges subsequently appeared in the March, 1907, issue of *National Geographic Magazine* in an article by Colonel Edwin F. Holmes, who advocated the formation of a national park to encompass the bridges. In 1907, Dean Byron

Cummings of the University of Utah led an expedition to investigate the bridges and the prehistoric ruins in their vicinity under the auspices of the Archaeological Institute of America. As a result of Cummings' expedition, President Theodore Roosevelt in 1908 proclaimed the area to be Natural Bridges National Monument in accordance with the Antiquities Act of 1906. It was the first national monument or park established in Utah. A second proclamation in 1909 by President Taft enlarged the boundaries of the monument to include further archeological sites. Three months after Cummings published an account of Rainbow Bridge and neighboring archeological sites in the February, 1910, issue of *National Geographic Magazine*, President Taft created Rainbow Bridge National Monument. Capitol Reef was made a State Park in 1925, and became Capitol Reef National Monument in 1937. Presidents Eisenhower and Johnson subsequently enlarged it, and in 1971, it became Capitol Reef National Park (Crampton 1959:74-81; Daughters of Utah Pioneers 1977:148-154; Woodbury 1944:196- 208).

By 1922, when the Colorado River Commission was initiated, the natural beauty of southeastern Utah was widely recognized. The final barrier to the full recreational exploitation of the region was removed in 1929 with the dedication of Navajo Bridge at Lee's Ferry. With the building of this bridge, easy access across the Colorado River led to a rapid increase in tourist activities throughout northern Arizona and southern Utah (Crampton 1959:81-84; Creer 1958a:24).

Chapter 4

Methods

As a background to interpreting the results of the survey, this chapter outlines the file search, our definitions of sites and isolated finds, and our survey and recording procedures. The rationale for the sampling design is also discussed at some length because of its importance to the density estimates and modelling results presented in Chapters 7 and 8.

File Search and Literature Review

Prior to the initiation of fieldwork, staff members from P-III Associates conducted literature reviews and file searches at the Utah State Historic Preservation Office in Salt Lake City and at the BLM Resource Area Offices in Price and Monticello. A number of previously recorded sites were located in or near all three project areas; however, none were located in any of the quadrats eventually selected for survey. The results of the file search and literature review are discussed in more detail in Chapters 3 and 5.

Sampling Procedures

The contract required a cultural resource inventory of 10% of the area in each study tract. It further required that the sample be divided into two phases each consisting of a 5% sample of the tract. The two-phase design was intended to provide two independent data sets, one with which to develop a site locational model, and another with which to test and refine the model. The contract also specified the use of cadastrally aligned 160-acre quadrats, and that the first 5% sample be chosen using a simple random sample.

A simple random sample was used for the second phase as well, because

1. Multivariate statistics, such as multiple regression and discriminant analysis, and all of the inferential statistics assume independent selection of the sample elements, i.e., a simple random sample. Computing these statistics with data from complex sampling designs can cause underestimation of the sampling error and should therefore be avoided (Kish 1957).
2. The sample size for each phase is small, statistically speaking, amounting to only 15 quadrats in Circle Cliffs and 34 quadrats in the San Rafael Swell. If a stratified sampling design were used to select the second 5% sample, the subsample from each stratum would be too small to make reliable inferences about that stratum.
3. By using the same procedure to select both samples, it is possible to test the samples against each other to see if both are representative and combine the samples to (a) produce more accurate estimates of population parameters, and confidence intervals and (b) produce a refined model based on all of the data rather than on one 5% sample. It would not be valid to compare or combine the results of samples from different sampling strategies because the level of precision would differ between the samples.

4. Stratification of a sampling universe improves precision only if the strata are more internally homogeneous than the sampling area as a whole with regard to the variable being studied (Plog 1976:141; Read 1975:59). If the strata are incorrectly identified (i.e., if the strata are less internally homogeneous than the sampling area as a whole with regard to the variable of interest), as has been the case in several stratified sample inventory projects in Utah (Hauck 1979b; Reed and Nickens 1980), the sample will not necessarily be representative of the actual variation within the strata and the standard error is likely to increase. The net result is a decrease in the precision of the estimate.

   Additionally, previous projects have shown that no one variable accounts for variation in site frequency and distribution (Christensen et al. 1983; Larralde and Chandler 1981). Thus, successful stratification, which will increase the internal homogeneity of the strata, must be accomplished using a multivariate approach. It seems highly unlikely that a multivariate stratification accurate enough to increase precision over that which can be obtained by a simple random sample could be implemented with our current state of knowledge. As archeologists, we have yet to explain, or even identify the full range of variables that affected locational decisions and their relative contributions to those choices.

5. Estimation of population parameters and confidence intervals is more straightforward with simple random samples than with other more complex sampling designs, because complicated correction factors must be used to obtain valid results in the case of the latter (Kish 1957).

For the Circle Cliffs and the San Rafael Swell tracts, the sample was chosen by (1) deleting state and private land and previously inventoried areas from the study tract or sampling universe, (2) dividing the remaining area into quarter sections, (3) consecutively numbering the quarter sections, and (4) selecting two consecutive 5% samples using a random numbers table. Each 5% sample in the Circle Cliffs tract consisted of 15 160-acre quadrats; in the San Rafael Swell tract each 5% sample consisted of 34 160-acre quadrats. The 10% sample for the Circle Cliffs and San Rafael Swell tracts represented approximately 4800 and 10,880 acres of BLM land, respectively.

Six quadrats in Circle Cliffs and three in the San Rafael Swell were reselected because they were partially or completely inaccessible. All of these areas were located on spires, mesa tops or buttes surrounded by vertical Wingate cliffs reaching up to 100 m. Reselected quadrats were replaced with the quadrat corresponding to the next number on the random numbers table. The locations of the final survey quadrats are shown in Figure 12 for Circle Cliffs and Figures 13 and 14 for the San Rafael Swell.

The sampling procedure was different for the White Canyon study tract because a 10% sample amounted to only 1050 acres or 6.5 160-acre quadrats. A two-phase design would have consisted of only three quadrats per sample, too few to be statistically representative for population estimates or modelling purposes. Therefore, seven quadrats were selected in a single 10% sample. At the direction of the BLM, state land within the White Canyon tract was not deleted from the sampling universe. The locations of the White Canyon survey quadrats are shown in Figure 15.

Inventory Procedures

The 105 survey quadrats were inventoried by three crews, each consisting of a crew chief and three to five crew members. The crews generally worked independently during the day; however, the crew chiefs met in the evenings to discuss problems, compare the results of the day's work and plan strategies for the following day. Crew sizes varied according to the terrain and number of sites anticipated for each quadrat. Crews attempted to complete one quadrat per day, moving on to a nearby quadrat if the first one was finished early enough in the afternoon. Quadrats with a high site density often required more than one crew-day to complete.

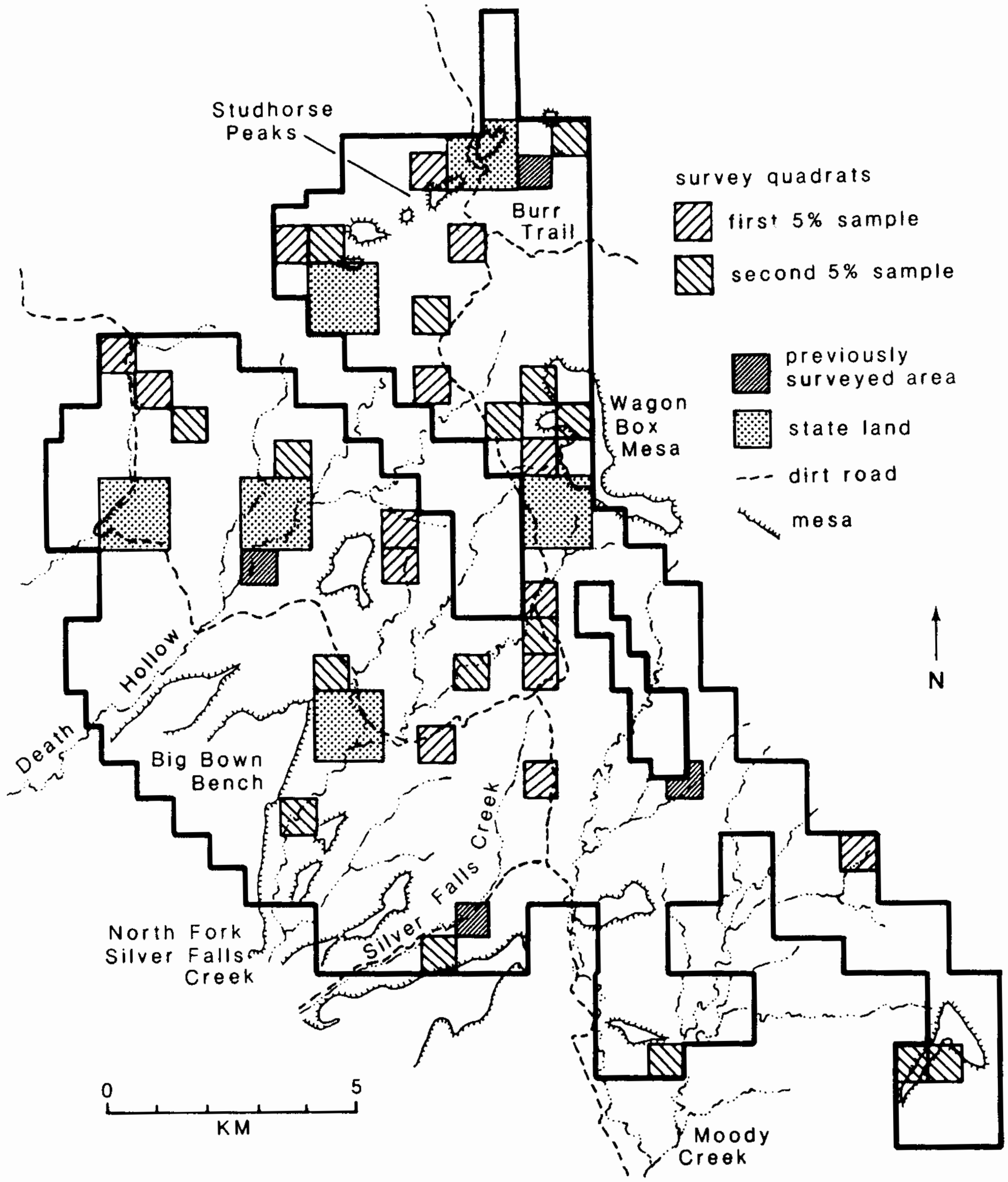

Figure 12. Map of the Circle Cliffs study tract showing previously surveyed areas and the location of the survey quadrats. Except as noted, all land is owned by the BLM.

The inventory parcels were located using a combination of U.S.G.S. topographic maps, section markers and three-way triangulation to prominent physiographic features. Relatively few difficulties were encountered in locating quadrats and quadrat boundaries because of the extreme relief in the project areas. When difficulty or uncertainty occurred, buffer zones were inventoried to insure complete coverage.

The inventory was accomplished on foot, in adjacent sweeps, with no more than 15 m between surveyors. Line-of-site compass bearings were used to orient the first sweep; toilet paper flagging was used to maintain continuity

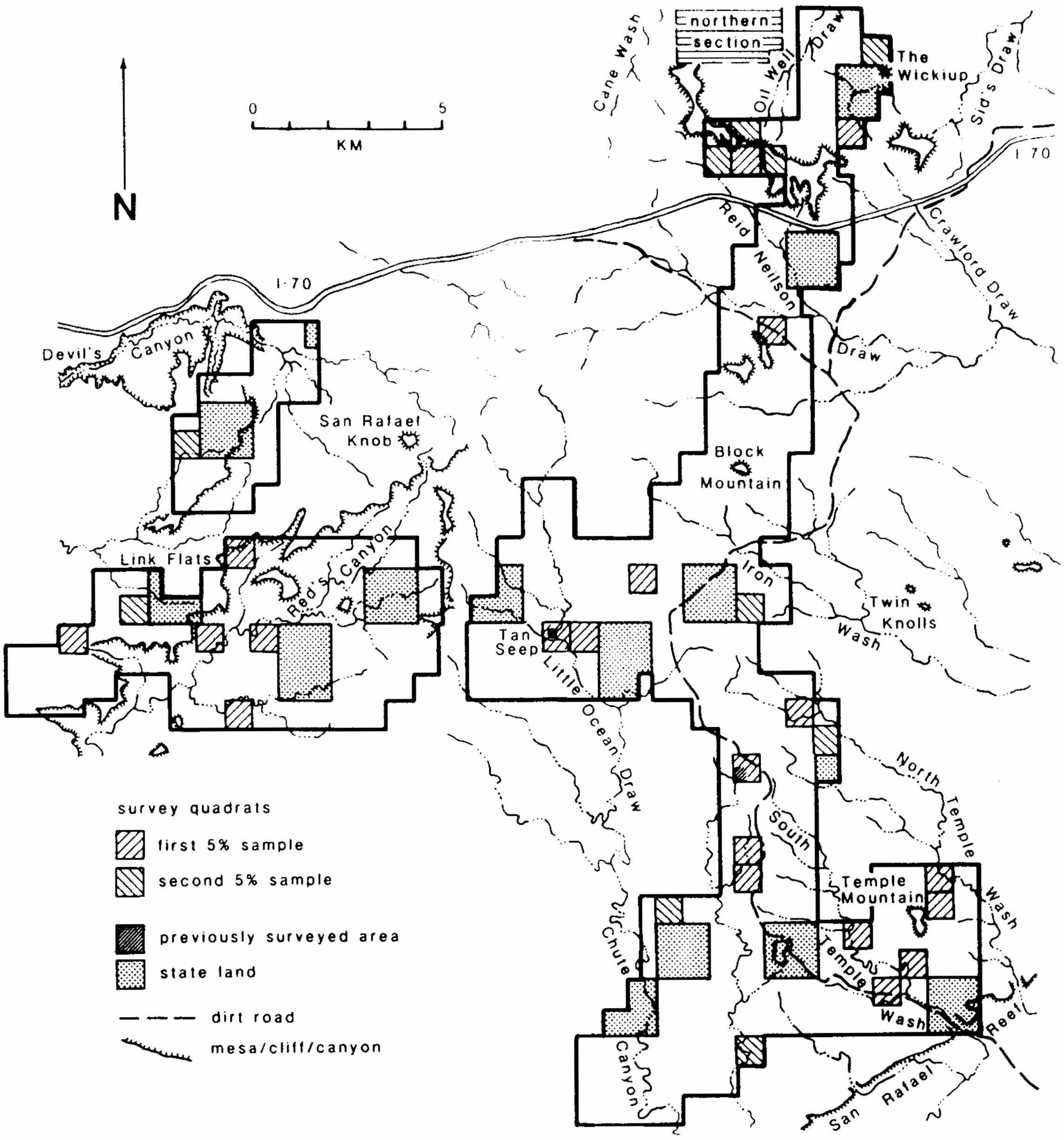

Figure 13. Map of the southern section of the San Rafael Swell study tract showing previously surveyed areas and the location of the survey quadrats. Except as noted, all land is owned by the BLM.

between sweeps. Steep talus slopes were surveyed in 15-m intervals by contouring, with all cliff bases and boulders on the talus slopes being carefully examined for rock art and other evidence of cultural activity.

Cultural resources were defined as identifiable loci of historic and prehistoric human activity. When a cultural resource was found, the the crew chief determined whether it should be recorded as a site or an isolated find. If features,

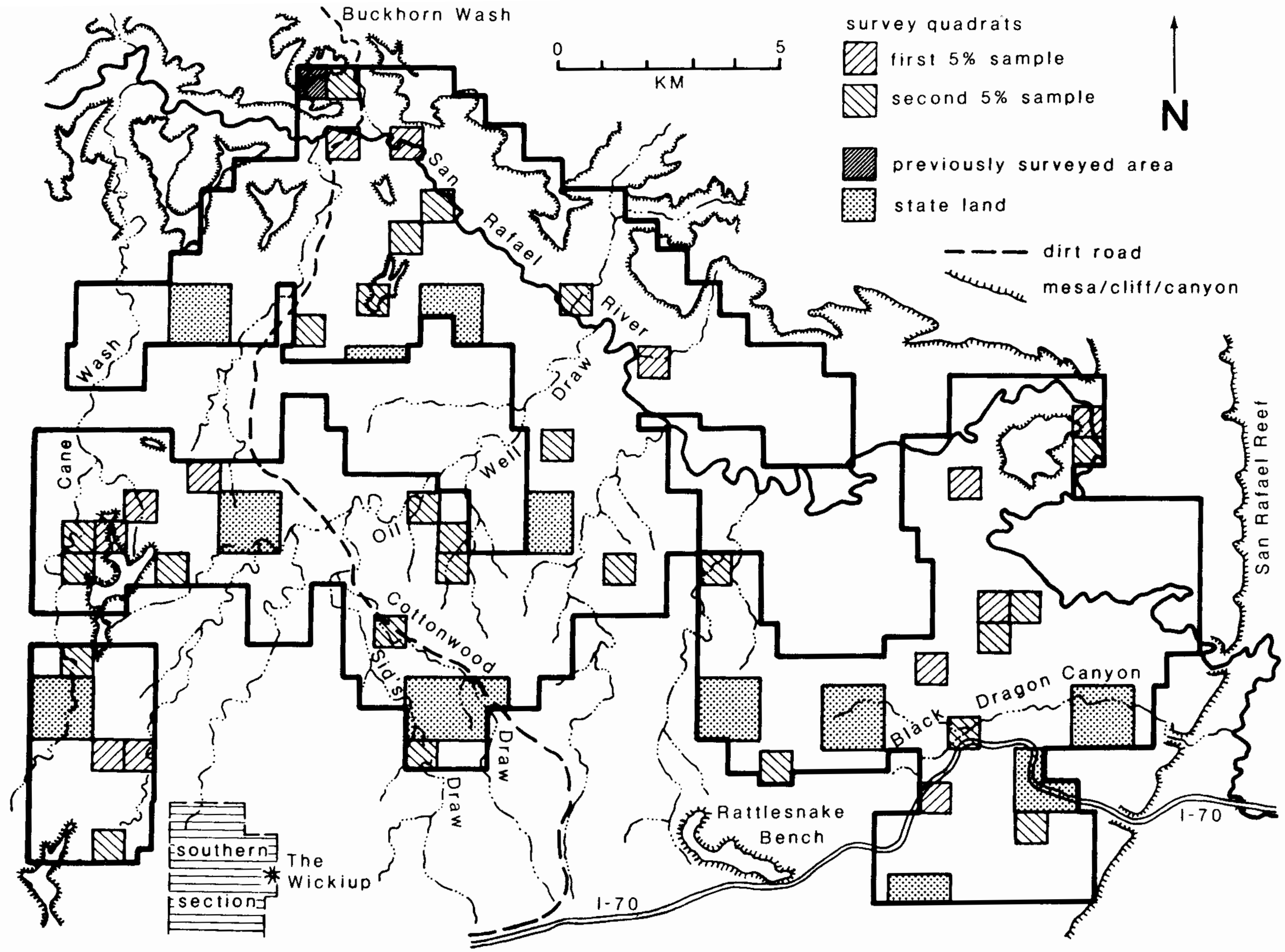

Figure 14. Map of the northern section of the San Rafael Swell study tract showing previously surveyed areas and the location of the survey quadrats. Except as noted, all land is owned by the BLM.

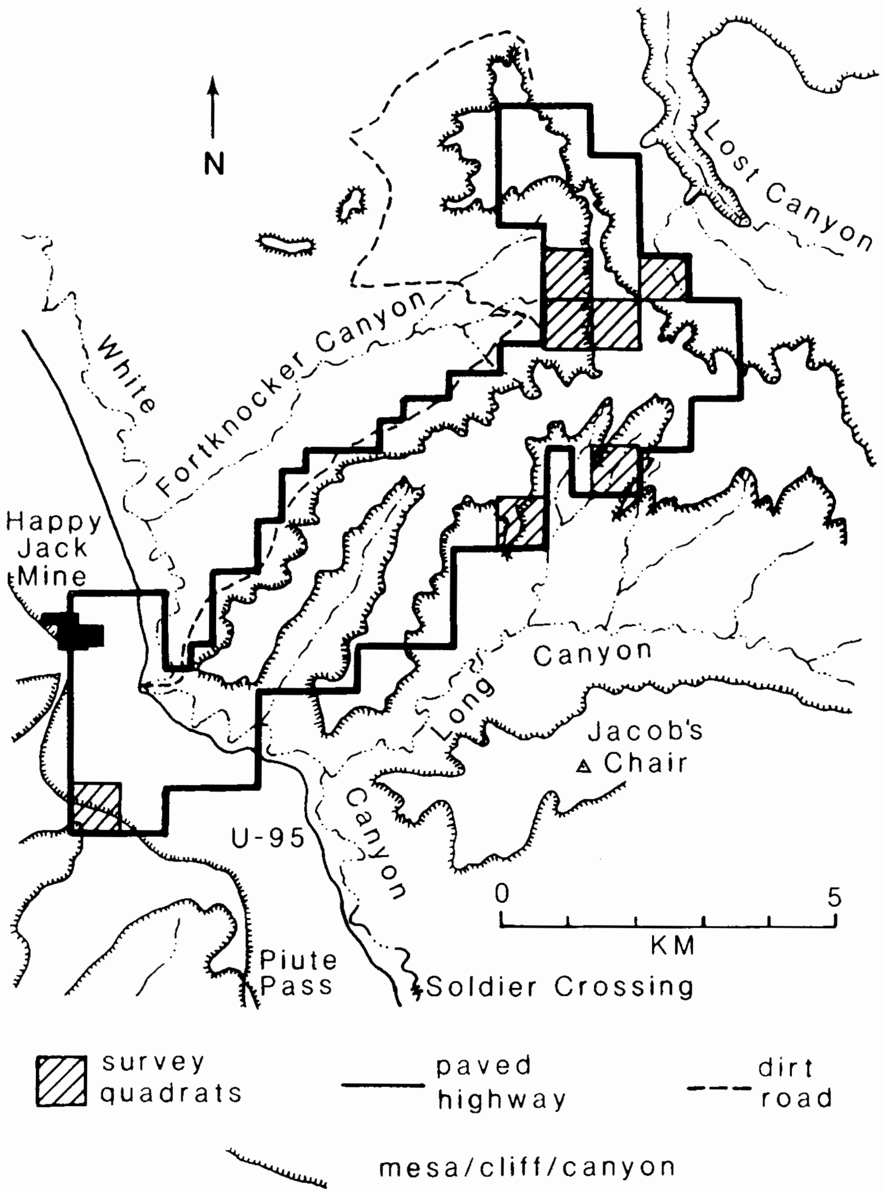

Figure 15. Map of the White Canyon study tract showing the location of the survey quadrats.

rock art, or at least five artifacts in a 10- by 10-m area were present, the locus was recorded as a site. Otherwise, the materials were recorded as an isolated find. The only exceptions were in situations where a single, momentary activity caused the deposition of more than five artifacts, that is, where a pot had been dropped and broken. These materials were recorded as isolated finds. Historic remains more than 50 years old were evaluated according to the same criteria. "Historic" finds post-dating 1935 were only recorded if they were extremely large, unusual, or if their location coincided with that of a prehistoric site. Otherwise, such finds were noted on the quadrat form and/or described with the isolated finds.

When a site was found, artifacts, concentrations of artifacts, tools, features and structures were marked with pin flags to help delineate site boundaries and artifact concentrations. After being thoroughly inspected, each site was then mapped, photographed and recorded on an Intermountain Antiquities Computer System (IMACS) site form. The crew chiefs were responsible for filling out the site forms, making all in-field significance evaluations and plotting sites on the most recent version of the U.S.G.S. topographic map available for the area. With the exception of three 1953 edition, preliminary 7.5 minute maps in the San Rafael Swell, the topographic maps used during the project are the 15 minute series produced in the 1950s. As part of the standard recording procedure, all sites without apparent depth were also probed to determine whether buried cultural deposits were present.

A paced scale map was also produced showing site boundaries, the location and size of any features, point provenienced artifacts, subsurface probes, the location and direction of photographs, the mapping datum, nearby topographic and man-made features, access routes, areas of recent disturbance, as well as contours and other pertinent information. Finished tools were generally drawn and described, unless the frequency was too great, in which case, only a sample was recorded in detail. Pottery and flake types, as well as lithic material types and their frequencies were recorded on the IMACS site forms.

Field collections were limited to potentially diagnostic artifacts (e.g., pottery and projectile points) and artifacts subject to unauthorized removal (e.g., projectile points, unusual perishable artifacts). Artifacts were plotted on the site map and assigned field numbers prior to collection and removal from the site. The Circle Cliffs materials are curated at Southern Utah State College in Cedar City, Utah. The materials collected in the San Rafael Swell and White Canyon are curated at the Edge of the Cedars Museum in Blanding, Utah. Paleontological finds were recorded on Part D of the IMACS site form.

Quadrat Summary Forms

Quadrat summary forms were completed for each quadrat by the crew chief responsible for the survey. These forms include management information such as the legal location of the quadrat, access routes, the number of corner sections located, inventory procedures, a description of any extra acreage inventoried and photograph numbers, as well as the names of the surveyors and the dates of inventory.

These forms also contain a summary of cultural resources including a list of sites, descriptions of isolated finds, a list of collected artifacts and an evaluation of the potential for subsurface sites in the quadrat. The environmental section includes information on the vegetation, surficial material, terrain, water and potential lithic sources. This information is summarized in Chapter 5 as it relates to the distribution of cultural resources.

Chapter 5

SUMMARY OF CULTURAL RESOURCES

Administrative Summary

The inventory resulted in the discovery and documentation of 155 previously unrecorded sites and 274 isolated finds within the 105 survey quadrats. Eleven additional sites and 10 isolated finds were discovered inside the project area boundaries, but outside of the survey quadrats. The file search revealed six other sites that had been previously recorded outside of the survey quadrats. Thus, there are a total of 172 sites and 284 isolated finds documented within the project area. Sites recorded during the present project are summarized below. The previously recorded sites are listed in Table 3. The isolated finds are discussed at the end of the chapter.

Of the total known sites, 163 are prehistoric, 3 are historic or recent and 6 contain both prehistoric and historic/recent components. Fifty-nine of the prehistoric sites, two of the historic/recent sites and four sites with both prehistoric and historic/recent components are located in Circle Cliffs. Of the 87 sites situated in the San Rafael Swell, 84 are prehistoric, 1 is historic and 2 have evidence of both. The remaining 20 sites, all located in White Canyon, are prehistoric. Table 4 shows the frequency of prehistoric and historic/recent sites in the survey quadrats by study tract. Table 5 presents this same information for the isolated finds. Descriptions, tabulations, and analyses of sites, isolated finds, features and artifacts in this and succeeding chapters only include materials found inside of the survey quadrats unless otherwise noted.

Cultural Affiliation and Age

Although very little previous work had been conducted in the actual study tracts, the sequences of cultural affiliation and chronological

Table 3. Summary of previously recorded sites in the project area.

Site Number	Location	Site Type	Reference
42GA87[a]	Circle Cliffs	Lithic scatter with possible hearth	Suhm 1959
42GA1636	Circle Cliffs	Lithic scatter	Hauck 1979b
42GA1637	Circle Cliffs	Lithic scatter	Hauck 1979b
42EM619	San Rafael Swell	Pictograph	BLM files
42EM707	San Rafael Swell	Lithic scatter, structure and petroglyphs	BLM files
42EM1105	San Rafael Swell	Petroglyphs and pictographs	BLM files

[a]The exact location of site 42GA87 is unknown although it appears to be in the project area.

Table 4. Frequency of prehistoric and historic/recent sites in survey quadrats by study tract.

Study Tract	Prehistoric	Historic/Recent	Prehistoric and Historic/Recent	Total
Circle Cliffs	50	1	3	54
San Rafael Swell	78	1	2	81
White Canyon	20	0	0	20
Total	148	2	5	155

Table 5. Frequency of prehistoric and historic/recent isolated finds in survey quadrats by study tract.

Study Tract	Prehistoric	Historic/Recent	Prehistoric and Historic/Recent	Total
Circle Cliffs	60	2	0	62
San Rafael Swell	167	15	3	185
White Canyon	27	0	0	27
Total	254	17	3	274

development are fairly well understood in the general project area (Jennings 1978). Using these sequences as baselines, we attempted to infer cultural affiliation and age for each site by cross-dating diagnostic artifacts and distinctive cultural features. The cultural affiliation of the historic sites was assumed to be Euroamerican, based on information gathered during the background literature review. The age of the historic sites was estimated based on diagnostic items such as plastic dishes and containers and aluminum and aerosol cans, as well as bottle and tin can styles and glass color (Berge 1980; Rock 1981a, 1981b). Pottery and projectile points were the main criteria used to ascertain the cultural affiliation and age of the prehistoric sites, although features such as roomblocks and rubble mounds were also considered. Projectile points were used to assign sites to Archaic or Numic cultural affiliation. Anasazi (cf. Colton 1955, 1956) and Fremont (cf. Madsen 1977) affiliations were generally inferred from pottery.

The age of the Archaic sites was estimated by cross-dating the projectile points using Holmer (1978), Benedict and Olson (1978) and Millar (1978). In general, Pinto, Humboldt Concave Base and Northern Side-notched points were considered characteristic of the Early Archaic which ranges from about 8300 to 6200 B.P. on the northern Colorado Plateau. Rocker, Hawken, Sudden and San Rafael Side-notched as well as McKean Lanceolate, Oxbow and Mt. Albion Corner-notched points were used to identify the Middle Archaic, dating from roughly 6200 to 3700 B.P. The Late Archaic, which lasted from approximately 3700 to 1500 B.P., was recognized by the presence of Gypsum points. Although Gypsum points are generally considered diagnostic of the Late Archaic (Schroedl 1976), Holmer (1978) observes that they occasionally occur on Fremont sites; thus, it is possible that some of the sites identified as Late Archaic could actually be Fremont.

Dates for the Anasazi and Fremont sites were ascertained on the basis of published dates for pottery types in surrounding regions—the Glen Canyon area (Ambler et al. 1964; Lipe 1967a) and greater Southwest (Colton 1955, 1956) for White Canyon, and the Ivie Creek area (Aikens 1967; Madsen 1975a; Madsen 1977) for the San Rafael Swell. These data were supplemented by temporal information available for various arrow points (Holmer and Weder 1980).

Sites containing points, pottery and/or features dating to one time period were assigned to the corresponding temporal range. When materials from more than one time period were present, further evaluations were made to determine whether there were multiple occupations, or whether there was simply a temporal overlap among diagnostic materials. Tables in Appendix 1 list the cultural affiliation and temporal placement of the individual sites.

Although several of the sites were vandalized, there did not appear to have been significant disturbance or artifact collection in most of the survey quadrats in the San Rafael Swell or White Canyon. Thus, the range of affiliation and age in the surveyed areas is probably relatively representative. Piles of artifacts on historic and recent sites in Circle Cliffs indicates that more artifact collecting has occurred in this tract, but probably not enough to invalidate the range in affiliation and age noted in this area.

General Summary

Analysis of the cultural affiliation and temporal placement of the 155 sites recorded in the survey quadrats resulted in the identification of 167 components, 9 historic/recent and 158 prehistoric and protohistoric. Temporal placement ranges from Early Archaic to the recent period, with Archaic, Fremont, Anasazi, Numic and Euroamerican affiliations being identified (Tables 6-7). Roughly 66% of the sites could not be associated with a particular affiliation or time period. These sites were assigned to the general category "prehistoric," a group that contains a wide variety of site types including lithic scatters lacking diagnostic artifacts and sites with features that are potentially datable through excavation and radiocarbon dating.

Within the overall project area, the majority of sites of known affiliation are Archaic, followed by Anasazi and Euroamerican. Fremont and Numic sites are only present in low frequencies (Table 6). White Canyon is characterized by a predominance of Anasazi sites and is the only tract containing unequivocal evidence of Pueblo occupation. Conversely, the few unmistakeably Fremont sites are confined to the San Rafael Swell. Sites of Archaic affiliation prevail in both the Circle Cliffs and San Rafael study tracts, with a few sites displaying Numic occupation. Although no Paleoindian sites were recorded, one site in the San Rafael Swell contained a Lake Mohave point which is Paleoindian or transitional from the Paleoindian to the Archaic period.

Circle Cliffs

Circle Cliffs study tract was inhabited by Archaic, Numic and Euroamerican peoples during the Middle and Late Archaic, Protohistoric and historic/recent periods, respectively. The presence of a pithouse dating to approximately A.D. 250 (see Chapter 6) indicates that the area may have also been utilized by Basketmaker or possibly early Fremont groups. Other evidence of a possible Basketmaker occupation is the occurrence of five side-notched Elko points which are considered diagnostic of Basketmaker II in the Four Corners area (Kidder and Guernsey 1919).

Although the survey did not reveal any direct evidence of Anasazi or Fremont occupation, such sites are present in the general Circle Cliffs area (Lister and Lister 1961; Dee Hardy, personal communication; Douglas McFadden, personal communication; personal observation). These known sites are located around the perimeter of, rather than in, the Circle Cliffs study tract.

Based on the limited data from the survey and our knowledge of Anasazi site locations in surrounding areas, we suggest that the paucity of Anasazi sites is related to the marginality of the

Table 6. Frequency of sites and components by cultural affiliation and study tract.

Cultural Affiliation	Circle Cliffs	San Rafael Swell	White Canyon	Total
Euroamerican	5	4	0	9
Numic	1	2	0	3
Anasazi	0	0	17	17
Fremont	0	6	0	6
Archaic	9	18	2	29
Unknown prehistoric	43	57	3	103
Total	58	87	22	167

Table 7. Frequency of sites and components by age and study tract.

Temporal Placement	Circle Cliffs	San Rafael Swell	White Canyon	Total
Historic/recent	5	4	0	9
Protohistoric	1	2	0	3
Protohistoric, Pueblo IV	0	0	1	1
Late Prehistoric, Pueblo II-III	0	0	16	16
Late Prehistoric, Fremont	0	6	0	6
Late Archaic	4	7	0	11
Middle Archaic	5	4	2	11
Early Archaic	0	7	0	7
Unknown prehistoric	43	57	3	103
Total	58	87	22	167

study tract for prehistoric agriculture. The portion of the Circle Cliffs valley that lies within the tar sands study tract is rugged and dry; most of the surface is covered with small, broken pieces of tabular sandstone and shale with very little arable alluvium or soil. The lack of water and arable soil make the study tract relatively unsuitable for prehistoric agriculture, particularly in relation to surrounding areas (e.g., White Canyon Flat, Onion Seep Flats, The Flats, the Aquarius Plateau) that are better watered and contain deposits of arable soil.

We hypothesize that the Anasazi maintained their habitation sites and/or base camps in these adjacent areas which were more suitable for farming and used the Circle Cliffs study tract to procure wild plant and animal resources on a temporary or seasonal basis. If this hypothesis is correct, some of the undiagnostic sites in the Circle Cliffs study tract could be Anasazi in origin.

The historic site and four historic/recent components discovered in Circle Cliffs roughly date between A.D. 1904 and 1963 (Figure 16). The component at site 42GA2572 consists of a scatter of sanitary cans as well as hole-in-the-top and matchstick filler hole evaporated milk cans. This component can be chronologically bracketed between A.D. 1904 and 1918 if all of the materials were deposited contemporaneously. Otherwise, the earliest date would be 1899, with the latest date in the recent past. The "component" at site 42GA2528 consists of a single amethyst glass, machine-made jar that was manufactured between A.D. 1904 and 1917.

The historic components at sites 42GA2540 and 42GA2542 evidently represent two areas of a single historic site. They could date as early as 1920 although the presence of aerosol cans, which were introduced in the 1940s (Berge 1980:262), suggests that they are more recent (Figure 16). The presence of squat, 2 lb, key-open coffee cans place the termination date prior to A.D. 1963, the year Hills Brothers introduced keyless cans with plastic covers (Rock 1981b:20). Artifacts from the historic site, 42GA2513, span the era between A.D. 1920 and the recent past, and include all-aluminum beer cans that were introduced by the Coors and Gunther brewers in A.D. 1959 (Rock 1981b:25). A date of A.D. 1960 or later is likely for this extensive habitation site.

San Rafael Swell

The San Rafael Swell study tract was inhabited by Archaic, Fremont, Numic and Euroamerican groups (Table 6). A Lake Mohave point recovered from a site in the northern end of the study tract may be indicative of Paleoindian presence. Among the sites identifiable to affiliation, Archaic is the most common making up over 60%. Fremont sites account for 20% of those identifiable to affiliation, fewer than expected given the geographic location of the study tract, but not surprising given the marginal conditions for horticulture compared to the Ivie Creek area immediately to the west (Aikens 1967; Madsen 1975a).

The San Rafael Swell has evidence of occupation during all of the chronological periods from the Early Archaic through the recent past. It is the only study tract where materials from all three phases of the Archaic were found.

Dates of a historic trash scatter and three historic/recent components recorded in the San Rafael Swell range from A.D. 1904 to the recent past (Figure 16). Extensive evidence of mining activities dating to the 1950s was also noted in the vicinity of Temple Mountain, Flat Top and throughout the study tract. Chapter 3 outlines the mining activities and provides a chronological account of other historic uses of the San Rafael Swell tar sands area.

The historic component at site 42EM1704 is evidenced by an oval, juniper brush corral, a scatter of amethyst glass and a hinge-lid tobacco tin. Amethyst glass is broadly dated between A.D. 1880 and 1917; hinge-lid tobacco tins were introduced in A.D. 1910. A date between A.D. 1910 and 1917 can be inferred for this component.

The historic site (42EM1738) and one of the other historic components (42EM1681) date between A.D. 1904 and 1917. The former is a small scatter of amethyst glass and matchstick filler hole evaporated milk cans. The later consists of purple glass fragments dispersed across a prehistoric site. The final historic component, found at site 42EM1712, contains several hearths and a trash scatter, and dates to sometime after A.D. 1910.

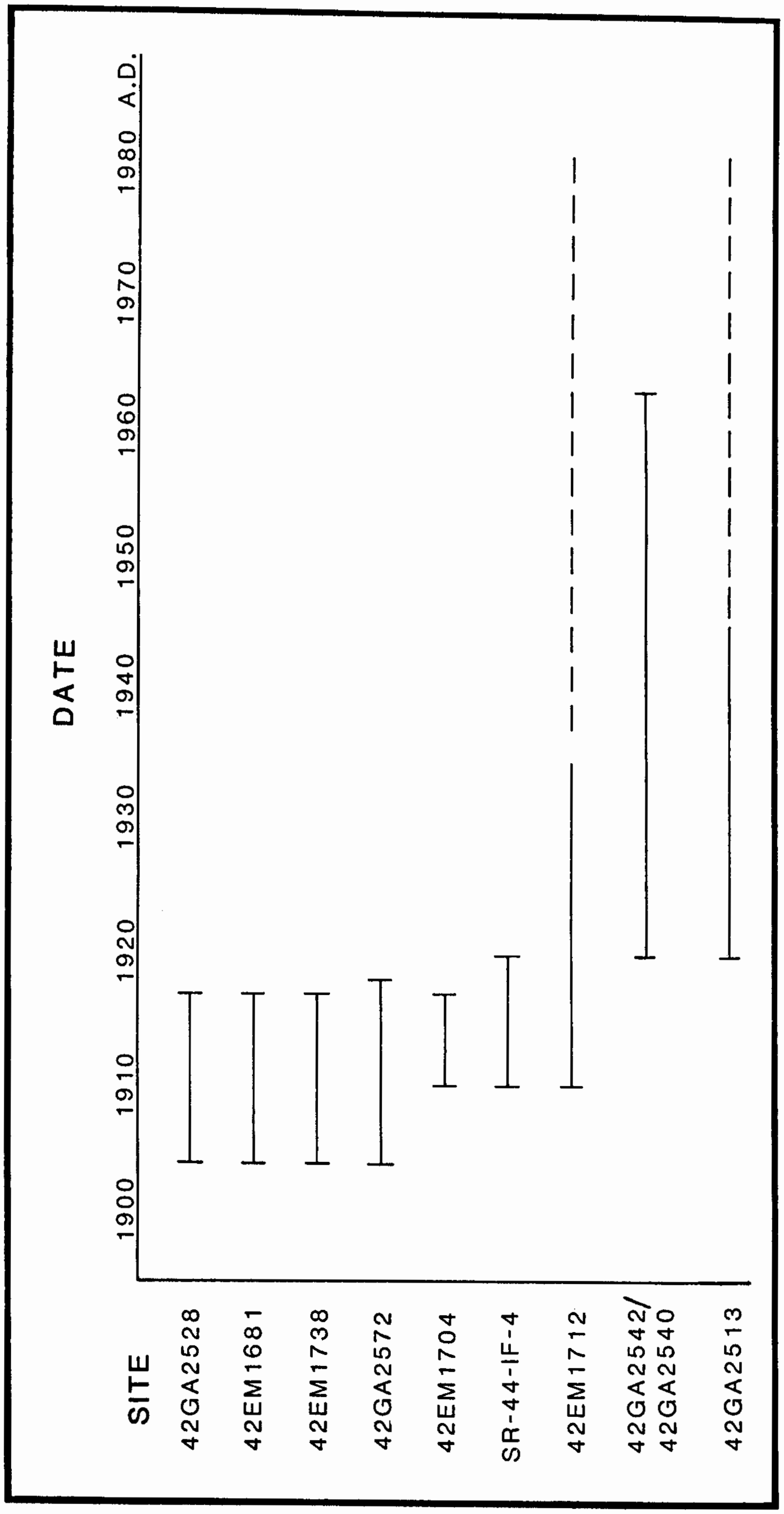

Figure 16. Estimated dates of historic/recent sites and an isolated find.

White Canyon

Data from the survey indicate that the White Canyon study tract was inhabited during the Middle Archaic and Late Prehistoric periods by Archaic and Anasazi peoples, respectively. As expected from previous research (Jennings 1966; Lipe 1967a; Sharrock 1964), the majority of sites are of Anasazi affiliation and date to the Pueblo II-Pueblo III time period; evidence of Basketmaker II and III, and Pueblo I are entirely lacking (Table 7).

In addition to the overwhelming evidence of a Pueblo II-III occupation, a limited amount of Jeddito Black-on-yellow and Jeddito Corrugated pottery is suggestive of occupation during the later Pueblo IV period. Lipe (1967a) believes that Pueblo IV Hopi pottery in southeastern Utah is indicative of Hopi presence for hunting and other specialized activities. Lucius (1983) attributes such pottery to Shoshonean use of Western Pueblo trade wares after A.D. 1400 (See Chapter 6).

Scanty evidence of the Fremont tradition—generally rock art depicting shield figures—has been noted by previous researchers in the White Canyon area (see Chapter 3), though most believe that the Fremont were generally confined to the area north and west of the Colorado River (Sharrock 1966; Thompson 1979). The lack of Fremont materials in the White Canyon tar sands area is consistent with previous research.

No historic sites were discovered in the White Canyon study tract although historical records demonstrate that the area was traversed by explorers, traders and outlaws, and later settled by ranchers, prospectors and Mormon pioneers. Chapter 3 outlines the chronological use of the area during the historic period and details an incident between the local Indians and a cavalry detachment that occurred just south of the study tract.

Site Typology and Function

by Betsy L. Tipps and Alan R. Schroedl

When developing site typologies for analytical purposes, researchers have often confused descriptive categories with functional types. The result of this confusion is that the analytical groups are not mutually exclusive and sites may belong to more than one category. For instance, some researchers distinguish between rockshelters, lithic scatters and extended and multiple occupation camps. Rockshelters and lithic scatters are descriptive categories, whereas extended and multiple occupation camps are functional classifications. From a functional perspective, rockshelter sites and lithic scatters could also be campsites. The groups are not parallel or mutually exclusive.

In order to avoid these polythetic, nonmutually exclusive categories, we distinguish between descriptive and functional site types and stress that descriptive classes do not automatically imply site function. Analyses of the frequency and types of features and artifacts present on sites in the three study tracts enabled us to identify 10 descriptive site types, as outlined below:

1. Lithic Source Area - Sites in this group are situated on natural occurrences of flakeable lithic material and contain evidence of on-site procurement of the lithic materials such as flaked cobbles, cores and blanks.
2. Lithic Scatter - Lithic scatters, the most common type of site encountered during the survey, are open sites evidenced by debitage. They may also contain ground stone and chipped stone tools.
3. Lithic Scatter with Features - Sites in this category are identical to the preceding group but are accompanied by features such as hearths, cists, ash stains, rock alignments and stone circles. More complex features requiring a high investment of labor and implying more extended use (e.g., pithouses or roomblocks) are included in other categories.
4. Sherd and Lithic Scatter - Sherd and lithic scatters are open sites characterized by lithic debris and pottery, and frequently, ground stone and chipped stone tools. Sherd and lithic scatters are distinguished from sites lacking pottery because the presence of pottery adds a chronological dimension to functional interpretations.

5. Sherd and Lithic Scatter with Features - This class is the same as the Sherd and Lithic Scatter noted above, but contains features indicative of low energy investment. Like the lithic scatters with features, sites exhibiting dwellings and other more permanent features are described in another category.

6. Masonry Architecture Site - This group of sites contains evidence of domestic masonry architecture such as rubble mounds, roomblocks and masonry structures. Most of these sites also exhibit expedient features as well as lithic and ceramic artifacts.

7. Pithouse - This category includes sites with evidence of subterranean pithouses. Only one site found within the survey quadrats, site 42GA2570, is included in this category.

8. Rockshelter - Rockshelter sites are evidenced by artifactual material in overhangs or alcoves; features are occasionally present. Generally, sites in this category have some potential for buried deposits and may have associated perishable remains.

9. Buried site - This category consists of open sites that have little or no indication of cultural material on the surface, but exhibit evidence of artifacts and/or buried cultural horizons in locations such as road cuts and side walls of erosional channels.

10. Historic site - This category includes all historic/recent sites and components.

At the outset of the project, rock art was expected given the number of well-known rock art sites in the immediate vicinity of the project area, particularly in the San Rafael Swell (e.g., the Temple Wash, Buckhorn Wash, Muddy-Rochester, Bug Eye and Lone Warrior panels) and White Canyon (e.g., Schaafsma 1971; Schroedl 1982; Steward 1941). The study tracts are primarily located in the Moenkopi, Shinarump and Chinle badlands, however, and contain few outcrops suitable for pictographs and petroglyphs. The lack of rock art is therefore not surprising.

Table 8 shows the frequency of sites and components by descriptive site type and chronological placement for each study tract. Tables in Appendix 1 list this same information by individual site. Predictably, lithic scatters are the most common site type, making up 60% of the total. The next most common category, lithic scatters with features, includes only 12% of the sites and components. The remaining 28% of the sites and components are distributed among the eight other categories.

Four prehistoric site types were identified in Circle Cliffs—lithic scatter, lithic scatter with features, rockshelter and pithouse (Table 8). Lithic scatter is the most common type of site composing over 70% of the sites and components in the study tract. Lithic scatters with features are considerably less common. Two pithouse sites were discovered during the survey; one was located in a road cut, outside of the survey quadrats. The rockshelter site and one of the lithic scatters with features each contain a large, circular stain that may also be a pithouse.

Although the San Rafael Swell has a higher diversity of site types than the other areas, lithic scatters are still the most common type of site accounting for roughly 62% of the total. Lithic scatters with features and rockshelters account for roughly 13% and 8%, respectively. In order of descending frequency, the other site types include buried sites, historic sites, lithic source areas, sherd and lithic scatters, and sherd and lithic scatters with features. The San Rafael Swell is the only study tract where lithic source areas and buried sites were identified.

In contrast to the other areas, masonry architecture sites are the most common type of site in the White Canyon study tract, reflecting the more permanent nature of the occupation in this area. Lithic scatters, and sherd and lithic scatters with features are also relatively common.

Among the Archaic sites recorded in the survey quadrats, lithic scatters, a few with features or buried components, are the predominant site types. The Fremont sites are generally sherd and lithic scatters; some contain features. The Anasazi sites are typically masonry architecture sites or sherd and lithic scatters with features,

Table 8. Frequency of descriptive site types for all sites and components by chronological placement and study tract.

Chronological Placement	Lithic Source Area	Lithic Scatter	Lithic Scatter w/Features	Sherd and Lithic Scatter	Sherd and Lithic Scatter w/Features	Masonry Architecture Site	Rockshelter	Pithouse	Buried Site	Historic Site	Total
					CIRCLE CLIFFS						
Historic	0	0	0	0	0	0	0	0	0	5	5
Protohistoric	0	1	0	0	0	0	0	0	0	0	1
Protohistoric, Pueblo IV	0	0	0	0	0	0	0	0	0	0	0
Late Prehistoric, Pueblo II-III	0	0	0	0	0	0	0	0	0	0	0
Late Prehistoric, Fremont	0	0	0	0	0	0	0	0	0	0	0
Late Archaic	0	2	2	0	0	0	0	0	0	0	4
Middle Archaic	0	5	0	0	0	0	0	0	0	0	5
Early Archaic	0	0	0	0	0	0	0	0	0	0	0
Unknown prehistoric	0	35	6	0	0	0	1	1	0	0	43
Subtotal	0	43	8	0	0	0	1	1	0	5	58
					SAN RAFAEL SWELL						
Historic	0	0	0	0	0	0	0	0	0	4	4
Protohistoric	0	2	0	0	0	0	0	0	0	0	2
Protohistoric, Pueblo IV	0	0	0	0	0	0	0	0	0	0	0
Late Prehistoric, Pueblo II-III	0	0	0	0	0	0	0	0	0	0	0
Late Prehistoric, Fremont	0	1	0	2	2	0	1	0	0	0	6
Late Archaic	0	5	1	0	0	0	1	0	0	0	7
Middle Archaic	0	4	0	0	0	0	0	0	0	0	4
Early Archaic	0	3	3	0	0	0	0	0	1	0	7
Unknown prehistoric	3	39	7	0	0	0	5	0	3	0	57
Subtotal	3	54	11	2	2	0	7	0	4	4	87
					WHITE CANYON						
Historic	0	0	0	0	0	0	0	0	0	0	0
Protohistoric	0	0	0	0	0	0	0	0	0	0	0
Protohistoric, Pueblo IV	0	0	0	1	0	0	0	0	0	0	1
Late Prehistoric, Pueblo II-III	0	0	0	2	5	9	0	0	0	0	16
Late Prehistoric, Fremont	0	0	0	0	0	0	0	0	0	0	0
Late Archaic	0	0	0	0	0	0	0	0	0	0	0
Middle Archaic	0	2	0	0	0	0	0	0	0	0	2
Early Archaic	0	0	0	0	0	0	0	0	0	0	0
Unknown prehistoric	0	2	1	0	0	0	0	0	0	0	3
Subtotal	0	4	1	3	5	9	0	0	0	0	22
Total	3	101	20	5	7	9	8	1	4	9	167

whereas all of the sites assigned to Numic affiliation are lithic scatters.

Although descriptive categories are adequate for summarizing the types and range of cultural resources in the three study tracts, they do not reflect function and are therefore less useful for interpretive purposes. We determined the function of the 158 prehistoric sites/components by evaluating eight criteria for each site. All of these variables are derived or calculated from categories on the IMACS site form: (1) diversity and size of the tool assemblage, (2) maximum density of artifacts, (3) frequency of debitage, (4) site size, (5) number of features, (6) type of features and amount of labor investment they represent, (7) presence of trash or midden deposits, and (8) presence of stratified deposits.

Diversity indices are used to measure the richness and evenness of a dataset, that is, to derive an index reflecting the number of groups (e.g., artifact classes) and the frequency and distribution of observations within these groups. They have been used in the context of biological and ecological research for a number of years and have recently been employed by archeologists as a means of deriving site function (Wood 1978). Higher index values are generally interpreted as evidence of multiple activities and longer occupation.

An index of the diversity of the tool assemblage at each site was calculated by the Shannon-Weaver diversity index using six artifact classes: projectile points, bifaces, unifaces, drills, ground stone and cores. This index is calculated by

$$\overline{H} = -\Sigma p_i(\log p_i)$$

where p_i is equal to the proportion of the number of items in the ith category to the total number of items at the site. This index ranges between 0 and 1, with larger values representing greater diversity.

The diversity index ranges between 0.00 and 0.65 for the 158 prehistoric sites and components recorded during the project. Fifty-four of the sites and components have an index of zero, indicating that there were either no tools, or that all of the tools were the same type (e.g, all bifaces). The highest value is for a habitation site in White Canyon that contains a number of artifacts from five different classes.

After computing the diversity index for each site, we conducted a principal components analysis (Nie et al. 1975) to concurrently evaluate the five interval level variables included in the analysis: diversity of the tool assemblage, maximum density of artifacts, frequency of debitage, number of features and site size. Site size was transformed into the base 10 log to reduce the range in the dataset. Principal components analysis is a multivariate data reduction technique that transforms the values on a series of variables into a single factor score. It maintains the structure of the original data set and can hence be considered a data transformation technique.

Two significant factors were derived; the first identified a continuum from large sites with high flake densities and high diversity indices to small sites with few or no tools and limited quantities of debitage. The second factor distinguished a continuum between sites with features and sites without. Because these two factors measure different variables, we simply summed them to obtain a single value for each site.

By examining the range and distribution of the added factor scores, we identified four groups to which we assigned functional names generally following Binford (1980). These types are limited activity site, field camp, base camp and habitation site. The sites were then examined on an individual basis to see if any should be reclassified in light of the three qualitative variables (type of features and amount of labor investment they represent, presence of trash and presence of stratified deposits). This intuitive assessment resulted in the reassignment of only a few sites.

Limited activity sites were used for specialized activities such as procuring lithic material and manufacturing and resharpening tools. The frequency of debitage may range from high to low, but the tool assemblage is limited in diversity and size, and indicative of a narrow range of activities. Limited activity sites lack features and are usually small.

Site 42GA2547, a typical limited activity site, consists of a small, sparse scattering of less than 25 chert and chalcedony flakes and 2 crudely flaked bifaces. The site covers an area of about 1000 m^2 and has a maximum artifact density of 4 flakes per m^2. Another limited activity site, 42EM1697, is a dispersed scatter of decortication and primary thinning flakes on a gravel terrace near the San Rafael River. It has a maximum density of 5 flakes per m^2, although the average density is much less. This unusually large site covers almost 54,000 m^2.

Field camps were used for short-term camping; trash, stratified deposits and features indicative of a high investment of labor are lacking. Expedient features such as hearths and rock alignments are occasionally present. Field camps have moderately diverse artifact assemblages that reflect a moderate range of activities. Artifact frequency and density are variable but usually low. Site size ranges from large to small.

Site 42EM1706 is a moderately large field camp covering an area of roughly 2600 m^2. It has three points, three bifaces, a core and a uniface resulting in a diversity index of .57. The total assemblage consists of less than 100 flakes and tools with a maximum density of 6 artifacts per m^2. Site 42GA2545, another field camp, consists of an extensive lithic scatter exhibiting 4 points, 2 bifaces and roughly 500 pieces of debitage. It covers an area of approximately 6100 m^2, and has a maximum density of 20 flakes per m^2 in the most dense portions of the site.

Because base camps were used for extended camping and temporary residence, trash deposits and relatively permanent facilities (e.g., stone structures, cists, rock alignments, etc.) are common. Base camps may also exhibit expedient features such as hearths and burned rock concentrations. The artifact assemblages are diverse and represent a wide range of activities. Debitage is present in significant quantities and usually moderately dense. Site size is often large, but can vary considerably. A few of the base camps lack features, but are included in this category because they cover a very large area and because they have numerous artifact concentrations, a diverse tool assemblage and a high frequency of debitage.

One of the more interesting base camps is site 42EM1696, an extensive scatter of chert and chalcedony flakes with 6 points, 12 bifaces, 14 cores, 4 pieces of ground stone and a light scattering of pottery. In the most dense areas of the site, artifact density reaches 750 items per m^2. This site has six hearths and covers more than 10,000 m^2.

Another base camp is site 42GA2525, which is a large scatter of debitage and chipped stone tools occurring in two discrete loci that contain at least 18 definable concentrations of artifacts. The tool assemblage includes 8 projectile points, 25 bifaces and a uniface. The site covers an area of over 53,600 m^2 and has a maximum density of roughly 20 flakes per m^2.

Habitation sites were used for permanent residence during at least a portion of the year. They have domestic architecture such as roomblocks, rubble mounds and pithouses in addition to other more expedient features. They frequently contain structured trash or midden deposits. The artifact assemblage usually includes a large number of tools and debitage and is indicative of a wide range of activities. Ground stone is frequently present. Site size ranges from medium to small. All of the habitation sites have buried deposits.

One of the more extensive habitation sites in the White Canyon study tract, site 42SA14418, consists of three ash stains or hearths, a midden, three rubble mounds and three flake concentrations. The surface artifact assemblage is composed of 4 bifaces, 5 projectile points, roughly 50 pieces of pottery and one piece of ground stone. The site is deeply buried and probably contains stratified deposits. It covers an area of more than 23,000 m^2.

Table 9 presents tabulations of the functional site types for the prehistoric sites and components by chronological placement and study tract. Field camps are the most common type of site discovered during the survey, comprising almost 50% of the total. Base camps are also relatively common, making up slightly more than 31%.

Table 9. Frequency of functional site types for prehistoric sites and components by chronological placement and study tract.

Chronological Placement	Limited Activity Site	Field Camp	Base Camp	Habitation Site	Total
CIRCLE CLIFFS					
Protohistoric	0	1	0	0	1
Protohistoric, Pueblo IV	0	0	0	0	0
Late Prehistoric, Pueblo II-III	0	0	0	0	0
Late Prehistoric, Fremont	0	0	0	0	0
Late Archaic	0	2	2	0	4
Middle Archaic	0	3	2	0	5
Early Archaic	0	0	0	0	0
Unknown prehistoric	13	22	7	1	43
Subtotal	13	28	11	1	53
SAN RAFAEL SWELL					
Protohistoric	0	0	2	0	2
Protohistoric, Pueblo IV	0	0	0	0	0
Late Prehistoric, Pueblo II-III	0	0	0	0	0
Late Prehistoric, Fremont	0	3	3	0	6
Late Archaic	0	2	5	0	7
Middle Archaic	0	2	2	0	4
Early Archaic	0	3	4	0	7
Unknown prehistoric	11	33	13	0	57
Subtotal	11	43	29	0	83
WHITE CANYON					
Protohistoric	0	0	0	0	0
Protohistoric, Pueblo IV	0	0	1	0	1
Late Prehistoric, Pueblo II-III	0	2	5	9	16
Late Prehistoric, Fremont	0	0	0	0	0
Late Archaic	0	0	0	0	0
Middle Archaic	0	0	2	0	2
Early Archaic	0	0	0	0	0
Unknown prehistoric	0	2	1	0	3
Subtotal	0	4	9	9	22
Total	24	75	49	10	158

Field camps are the most common type of site in Circle Cliffs and the San Rafael Swell accounting for roughly 50% of the sites in both areas. The San Rafael Swell has a higher percentage of base camps than Circle Cliffs and a lower proportion of limited activity sites. Although the San Rafael Swell may have been utilized more intensively, the frequency of the various site types indicates that both areas were primarily used on a temporary and seasonal basis, much as would be expected in a predominantly hunting and gathering economy. This comes as no surprise, of course, given that both areas were utilized more heavily during the Archaic than during later periods.

White Canyon is characterized by a radically different settlement pattern that focuses on habitation sites and base camps. There is much less evidence of temporary use in the quadrats inventoried (Table 9).

All of the sites and components identified as Archaic are field camps or base camps, though base camps are slightly more common. Both site types occur during all three phases of the Archaic, in roughly equal proportions, demonstrating consistency in the settlement pattern through time. The Fremont sites are also field or base camps which reflect seasonal rather than year-round occupation. In contrast, most of the Anasazi sites are habitations or base camps. Like the Archaic and Fremont sites, the Numic sites are either field or base camps.

Environmental Correlates of Site Location

The study of cultural adaptation in relation to environmental parameters can be traced to the pioneering studies of culture and environment by Steward in the 1930s (1936, 1938). As a means of better understanding human adaptation and prehistoric cultural behavior, archeologists have become increasingly interested in quantifying the relationship between site location and environmental factors through the use of mathematical and theoretical models. Two general approaches to this problem have emerged. The first attempts to identify and explain the determinants of human behavior (Jochim 1976; Wood 1978) based on theories borrowed from geography, economy, biology, ecology, etc. (Bettinger 1980).

The second approach focuses on identifying environmental variables that are correlated with site location (Kohler 1983) and is generally used in a management context for the purposes of planning and predicting site density and distribution in unsurveyed areas. It is noteworthy that the correlations identified in such models do not necessarily imply causality because the analytical variables may be vicarious or proxy measures for some other important factor. For example, it may be shown that sites in a given area always occur in side canyons to the main drainage. The high correlation says nothing about the factors that actually caused the prehistoric people to camp in the side canyons. It could be that they were warmer, more sheltered, or that they contained better tasting spring water, among other reasons. Thus, correlation models only indirectly contribute to our understanding of human behavior by the use of variables (e.g., distance to water, quality of shelter) that have explanatory value.

Because the purpose of this project was to gather data for planning and predictive purposes, we used a correlation approach to investigating site location in the project area. Chapter 7 presents an extended discussion of site density; Chapter 8 outlines the development of a mathematical predictive model of site location based on map-readable environmental variables. Because the small size of the sample in each study tract precluded the development of a statistically valid predictive model for each individual area, data from Circle Cliffs and the San Rafael Swell were combined for the modelling effort. White Canyon was excluded because of the extremely small size of the sample (i.e., seven quadrats) and because it has a strikingly different pattern of prehistoric settlement.

Realizing that the development of a single model for Circle Cliffs and the San Rafael Swell obscured some of the variability between the two areas and its effects on site location, this section outlines some of the environmental characteristics that appear to be correlated with site location in each study tract. Although our discussions are primarily descriptive rather than explanatory in nature, we hope that the information will be useful to researchers developing behavioral models in the future.

General Summary

In order to identify the environmental factors that correlate with site locations in the three tar sands study tracts, we encoded the site data on the IMACS code sheets, entered the information into the IMACS User's File, an advanced and refined version of the ARIS data file on the DEC-20 system at the University of Utah, and analyzed the data by remote processing.

For this particular analysis, we tabulated eight environmental variables that are usually considered important to both hunter-gatherer and agricultural populations. These included topographic features such as elevation, aspect, slope and landform as well as distance to permanent water. We also examined differences in the depositional environments of the sites and the primary and secondary on-site vegetation. Tables 10 through 12 present the tabulations and average values for each variable by study tract.

The average elevation of sites in Circle Cliffs and the San Rafael Swell differs by only 2 m (Table 10), even though the range of elevation in the San Rafael Swell (1280-2400 m) is more than twice the range in Circle Cliffs (1675-2195 m). The White Canyon sites lie at an average elevation of 1740 m, roughly 200 m lower than the other study tracts (Table 10). Yet, the minimum (1340 m) and maximum (2074 m) elevations in the White Canyon study tract are similar to those in the other areas. The apparent preference for lower elevation may be the result of sampling error, as 16 of the 20 sites are located in one relatively flat quadrat, but could also be because the White Canyon study tract was inhabited by Puebloan farmers who wanted to insure a sufficient frost-free period for the maturation of their crops. The average elevation of sites in Circle Cliffs and the San Rafael Swell provides the minimum number of frost-free days needed to cultivate prehistoric maize (Hack 1942).

The average aspect of prehistoric sites is relatively similar in all three study tracts, although sites in White Canyon have a slightly more

Table 10. Mean elevation, aspect, slope and distance to permanent water of prehistoric sites and components by study tract.

Variable	Circle Cliffs	San Rafael Swell	White Canyon	All Study Tracts
Elevation (m)				
Mean	1937	1935	1740	1910
Standard deviation	114	178	39	160
Aspect				
Mean	258°	296°	210°	271°
Standard deviation	212°	225°	119°	210°
Slope				
Mean	4.3°	3.9°	3.2°	3.4°
Standard deviation	5.1°	3.8°	1.2°	4.1°
Distance to permanent water (km)				
Mean	6.4	2.5	10.5	4.9
Standard deviation	2.6	2.3	0.7	3.6
Sample Size	53	80	20	153

Table 11. Frequency of prehistoric sites and components by landform, depositional environment and study tract.

Variable	Circle Cliffs *n*	Circle Cliffs %	San Rafael Swell *n*	San Rafael Swell %	White Canyon *n*	White Canyon %	All Study Tracts *n*	All Study Tracts %
Primary landform								
Tableland/mesa	34	64.2	30	37.5	20	100.0	84	54.9
Ridge	1	1.9	0	0.0	0	0	1	0.7
Valley	10	18.9	37	46.3	0	0	47	30.7
Canyon	8	15.1	13	16.3	0	0	21	13.7
Secondary landform								
Alcove	3	5.7	7	8.8	0	0.0	10	6.5
Basin	1	1.9	1	1.3	0	0.0	2	1.3
Dune	0	0.0	0	0.0	5	25.0	5	3.3
Ledge	0	0.0	0	0.0	2	10.0	2	1.3
Mesa	9	17.0	4	5.0	1	5.0	14	9.2
Plain	0	0.0	4	5.0	2	10.0	6	3.9
Ridge/knoll	31	58.5	33	41.3	6	30.0	70	45.8
Slope	2	3.8	1	1.3	0	0.0	3	2.0
Terrace/bench	6	11.3	26	32.5	4	20.0	36	23.5
Valley	0	0.0	4	5.0	0	0.0	4	2.6
Cut bank	1	1.9	0	0.0	0	0.0	1	0.7
Depositional environment								
Talus	1	1.9	0	0.0	0	0.0	1	0.7
Dune	3	5.7	6	7.5	10	50.0	19	12.4
Stream terrace	0	0.0	5	6.3	0	0.0	5	3.3
Alluvial plain	5	9.4	8	10.0	0	0.0	13	8.5
Colluvium	0	0.0	8	10.0	0	0.0	8	5.2
Outcrop	2	3.8	2	2.5	2	10.0	6	4.0
Eolian	1	1.9	20	25.0	8	40.0	29	19.0
Residual	41	77.4	31	38.8	0	0.0	72	47.1
Total	53		80		20		153	

southerly exposure than those in the other areas (Table 10). Average on-site slope ranges from 3.2° in White Canyon to 4.3° in Circle Cliffs, indicating, as expected, that relatively flat terrain was preferred for site location.

The average distance to permanent water varies considerably between the three study tracts (Table 10) ranging from 2.5 km in the San Rafael Swell to 10.5 km in White Canyon. The distance is shortest in the San Rafael Swell because the Swell has several major springs and because it is bisected by the San Rafael River. Given the geological formations exposed in the White Canyon study tract, there are probably a number of small, unrecorded, springs that are closer to the sites than the Colorado River, the permanent water source used for this analysis.

Table 12. Frequency of prehistoric sites and components by vegetation type and study tract.

	Circle Cliffs		San Rafael Swell		White Canyon		All Study Tracts	
Variable	*n*	%	*n*	%	*n*	%	*n*	%
Primary vegetation								
Pinyon-juniper	47	88.7	62	77.5	12	60.0	121	79.1
Desert shrub	0	0.0	8	10.0	1	5.0	9	5.9
Grass	4	7.5	6	7.5	1	5.0	11	7.2
Sagebrush	1	1.9	3	3.8	5	25.0	9	5.9
Barren	1	1.9	1	1.3	1	5.0	3	2.0
Secondary vegetation								
Pinyon-juniper	4	7.5	1	1.3	6	30.0	11	7.2
Desert shrub	35	66.0	51	63.8	8	40.0	94	61.4
Grass	4	7.5	22	27.5	0	0.0	26	17.0
Sagebrush	4	7.6	4	5.0	6	30.0	14	9.2
Barren	6	11.3	2	2.5	0	0.0	8	5.2
Total	53		80		20		153	

The actual distance to permanent water is probably less.

Sites were found on only four primary landforms: tableland/mesa, ridge, valley and canyon (Table 11). Slightly over half of the sites are located in tableland/mesa settings, while roughly 30% are situated in open rolling valleys. In Circle Cliffs, tableland/mesa is the most common primary landform, probably reflecting the relatively homogeneous topography of this study tract. Sites are more evenly distributed among the landforms types in the San Rafael Swell, a result of the topographic diversity in this area.

There is greater variability in the secondary landform, although the majority of sites are situated on ridge/knoll or terrace/bench topography. Ridge/knoll is the modal category in all three study tracts accounting for 58.5% of the sites in Circle Cliffs, 41.3% in the San Rafael Swell and 30.0% in White Canyon. Mesa tops were also a favored location in Circle Cliffs. In the San Rafael Swell, terraces, benches and alcoves were more popular. White Canyon differs from the other study tracts because it contains extensive dune deposits, a setting that was clearly preferred for site location (Table 11).

More than three-fourths of the sites in Circle Cliffs are situated on residual soil, the primary surficial material exposed in this area. Residual soil is also the modal category in the San Rafael Swell, but is found on only 38.8% of the sites; eolian, colluvial and alluvial environments are also relatively common. Sites do not occur on residual soils in the White Canyon study tract—though such soils are present—but are mainly located on sand dunes or eolian deposits. Except for White Canyon, the differences in the depositional environment seem to be the result of the type and amount of surficial materials exposed in each tract, rather than the deliberate selection of a particular depositional setting.

As expected, based on the results of other projects in the general area (e.g., Hauck 1979a, 1979b; Kearns 1982; Thompson 1979), pinyon-juniper woodland is the predominant primary vegetation on prehistoric sites in all three study tracts (Table 12). White Canyon is the only study tract where another vegetation community predominates on a significant portion of the sites. This community, sagebrush, rarely occurs in the other two tar sands areas.

The desert shrub community is the most common secondary vegetation type in all three tracts, though it occurs on a lower percentage of the sites in White Canyon than the other two areas. Pinyon-juniper and sagebrush vegetation are also common as the secondary vegetation on sites in White Canyon. In contrast, grassland vegetation is the second most common vegetation type on sites in the San Rafael Swell.

Table 13 shows the frequency of quadrats with and without sites by the primary and secondary geologic formation exposed within the quadrat, as determined from geologic maps. Chinle, Shinarump and/or Moenkopi formation is the primary geologic substrate in all quadrats—those with sites and those without sites—in Circle Cliffs. These same formations predominate in both the site and nonsite categories in the San Rafael Swell, although sites occur in most of the quadrats that have some other primary geologic substrate. None of the sites in White Canyon are located in quarter sections where one of these formations dominates. The modal category for secondary geologic substrate in quadrats containing sites, however, is Chinle, Shinarump and/or Moenkopi formation in all three study tracts.

Correlations between environmental variation and site location are more informative when they can be associated with cultural affiliation or chronological placement. The low number of sites that could be identified to affiliation and age precluded an extensive analysis, but preliminary tabulations identified two variables, elevation and distance to permanent water, that appear to vary between the temporal periods. However, because of the small size of the sample, it is not clear whether these differences are the result of random variation or preferences for certain site locations through time.

Table 14 shows that Late Archaic sites are generally found at higher elevations than Middle and Early Archaic sites and that Pueblo II-III Anasazi sites occur at lower elevations than sites of other affiliation. On the average, Middle Archaic sites are farther away from permanent water sources than other Archaic sites (Table 15). Pueblo II-III Anasazi sites are farthest from a permanent water source, but as noted above in the context of the White Canyon study tract, these figures do not take into account unrecorded springs that are probably present at the contact between certain geologic strata exposed in and near the study tract.

The tabulations of various environmental characteristics for each of the three study tracts reveal a number of similarities, but they also show that each area has individuality and important environmental characteristics that apparently played a significant role in the site selection process. These tabulations have also demonstrated that no one factor accounts for the variability in site location, confirming the common belief that predictive modelling can only be accomplished using a multivariate approach.

In closing this section, it should be noted that the areas included by the BLM in all three study tracts appear to have been selected to maximize the exposure of the Moenkopi and Chinle formations—presumably because they contain the tar sands. Both of these formations erode into steep talus slopes and badlands that are relatively undesirable for human habitation. Thus, our sampling universe is biased in that it contains a disproportionate amount of the rugged badlands, while the adjacent, open, flat and rolling country is underrepresented. The few quadrats that extended into the more desirable areas had a much higher site density and different patterns of prehistoric human occupation. Thus, the correlations between environmental variables and site location identified in this and succeeding chapters should only be applied to areas within the actual study tracts.

The preceding paragraphs outlined some of the quantifiable differences in the environmental parameters correlating with prehistoric site location between the three study tracts, as indicated by data from the IMACS site forms. The following sections discuss our intuitive feelings about prehistoric site location by study tract.

Table 13. Frequency of quadrats with and without sites by primary and secondary geologic substrate and study tract.

	Circle Cliffs		San Rafael Swell		White Canyon		All Study Tracts	
Variable	w	w/o	w	w/o	w	w/o	w	w/o
Primary geologic substrate								
Quaternary	0	0	2	0	0	1	2	1
Carmel, Navajo, Kayenta and/or Wingate	0	0	4	0	1	0	5	0
Chinle, Shinarump and/or Moenkopi	18	12	15	39	0	1	33	52
Kaibab, Coconino, and/or Cutler	0	0	6	2	2	2	8	4
Secondary geologic substrate								
Quaternary	2	1	3	2	1	1	6	4
Carmel, Navajo, Kayenta and/or Wingate	2	1	4	2	0	0	6	3
Chinle, Shinarump and/or Moenkopi	11	8	14	33	2	1	27	42
Kaibab, Coconino, and/or Cutler	3	2	6	4	0	2	9	8
Number of quadrats	18	12	27	41	3	4	48	57

NOTE: w = with sites; w/o = without sites.

Circle Cliffs

The Circle Cliffs study tract is a rectangular or crescent-shaped area located in a broad valley surrounded by high plateaus, mesas and cliffs. The valley floor is characterized by ridge and drainage badland topography that is dissected by several major drainages and dotted with massive sandstone-capped mesas (Figures 2-4). Most of the area is covered with pinyon-juniper woodland vegetation though the density varies considerably. Relative to the San Rafael Swell, the environment is relatively homogeneous.

Most of the sites in Circle Cliffs seem to occur on the ubiquitous ridges overlooking small drainages and the badland topography. Sites also occur on terraces above small intermittent tributaries. The surficial deposits in both of these locations usually consist of small pieces of broken sandstone and shale, covered with a thin veneer of eolian sand. Pinyon-juniper is the predominant vegetation.

Sites also occur on the mesa tops (e.g., Deer Point, Wagon Box Mesa and Studhorse Peaks), particularly around access routes and drainage heads. The primary substrate is usually bedrock covered with small, tabular pieces of sandstone and shale as well as a thin layer of eolian sand. On Deer Point, the sites occur in sandy basins. Pinyon-juniper is again the predominant vegetation.

Table 14. Mean elevation of prehistoric sites and components by chronological placement.

Chronological Placement	Mean (m)	Standard Deviation
Protohistoric	1913	29
Protohistoric, Pueblo IV	1737	-
Late Prehistoric, Pueblo II-III	1738	8
Late Prehistoric, Fremont	1924	187
Late Archaic	2012	191
Middle Archaic	1950	75
Early Archaic	1907	129
Unknown prehistoric	1926	157

Table 15. Mean distance from prehistoric sites and components to permanent water by chronological placement.

Chronological Placement	Mean (km)	Standard Deviation
Protohistoric	2.85	0.21
Protohistoric, Pueblo IV	10.20	-
Late Prehistoric, Pueblo II-III	10.17	0.25
Late Prehistoric, Fremont	1.40	1.03
Late Archaic	3.20	2.98
Middle Archaic	6.27	4.07
Early Archaic	1.67	1.23
Unknown prehistoric	4.40	3.26

The fourth major site location in Circle Cliffs is the open valleys adjacent to major intermittent drainages (e.g., Silver Falls and Moody Creek). These areas are characterized by deposits of alluvial and colluvial sediment and support both grassland and pinyon-juniper vegetation. It is also noteworthy that quadrats supporting a more dense pinyon-juniper woodland generally contain more sites than quadrats with sparse pinyon-juniper vegetation. The quadrats with less vegetation are more rugged and steep, however, and primarily consist of Chinle and Moenkopi ridges and talus.

Predictably, sites do not occur on talus slopes or steep terrain. They are also lacking in areas where broken pieces of sandstone, shale and mudstone are present on the surface in the absence of eolian deposits. Surprisingly, sites do not seem to occur along the rims of the larger drainages or in alcoves situated within these drainages.

San Rafael Swell

In contrast to Circle Cliffs, the long and narrow San Rafael Swell study tract has greater environmental diversity, which apparently caused greater aggregation of the prehistoric sites. The northern end of the San Rafael Swell study tract, known as Sinbad Country, is characterized by open, rolling topography dotted with limestone mesas and benches and incised by several major tributaries. Sites are primarily concentrated on the flat benches along these major drainages (e.g., Sids Draw, Lockhart Draw and Cottonwood Draw) and in alcoves and overhangs inside the drainage rims (e.g., Oil Well Draw). These drainages are generally incised into the Kaibab Limestone and contain plunge pools and potholes that would have been good sources of seasonal water. They also provide access through the San Rafael Reef and may have been major travel routes through the northern end of the Swell.

Evidently, mesa tops were not a favored site location in the northern end of the San Rafael Swell, particularly those capped with rough limestone bedrock. Sites are found on the more southerly mesas near Interstate 70; these mesas are generally capped with Shinarump Conglomerate overlain by dune deposits or eolian sand.

Except for the area around Taylor Flat and Tan Seep (Figure 5), the southern section of the San Rafael Swell study tract is much more rugged than the northern section and consists of extremely dissected tablelands, high mesas (e.g., Temple Mountain) and deep drainages (e.g., Reds Canyon and Sulphur Canyon [Figures 7-9]). The predominant substrate is small pieces of tabular sandstone or mudstone. Quaternary deposits such as sand, alluvium and colluvium are generally lacking. Except for a few limited activity sites located along drainages or on isolated dunes, the rugged portion of the southern section is relatively devoid of cultural resources.

Sites in the Tan Seep/Taylor Flat area occur in several environmental settings: on knolls and low relief ridges in the pinyon-juniper woodland, on the high ridges overlooking Tan Seep in a desert shrub association, and in the alluvial deposits surrounding Tan Seep and Little Ocean Draw in both desert shrub and sagebrush vegetation.

The western portion of the study tract, which includes Link Flats, Sagebrush Bench and the Dike, is characterized by low relief mesa tops and narrow valley flats surrounded by high sandstone ridges and mesas. Dunes are relatively common. Sites generally occur on large, stabilized dunes or on low relief ridges in the narrow valley floors. The western area of the San Rafael Swell study tract has the highest site density and a number of large, multiple activity base camps. Sites in all portions of the San Rafael Swell tar sands area occur on level terrain in or near the pinyon-juniper woodland.

White Canyon

The White Canyon study tract consists of tablelands that are dotted with low sandstone and shale mesas and high, cliff-bound sandstone mesas, and that are dissected by several major canyons and their tributaries. Some of the tablelands are covered with pinyon-juniper woodland vegetation with a sagebrush understory. Other areas support a predominantly blackbrush community.

In general, sites occur on both the tableland flats and high, cliff-bound mesas. They are also concentrated in the pinyon-juniper woodland where a sagebrush understory predominates. Most of the sites occur on fairly level terrain, in sandy deposits or on eolian-covered outcrops. They do not seem to occur on the low, sandstone and shale mesas with rugged, dissected tops or in the the blackbrush association. They are also lacking where eroding sandstones, shales and mudstones are the primary surficial material.

Sites are found in two main settings within the White Canyon study tract. The first is atop the high mesas located at the southern and western margin of the tract. Sites in this setting are usually situated on small ledges around the heads of drainages and lie on Navajo sandstone bedrock or shallow accumulations of eolian material in a sparse pinyon-juniper woodland. The other main site location – where 16 of the 20 sites found during the survey are located – is the pinyon-juniper woodland-covered flats overlooking Lost Canyon. All of these sites are situated in dune or eolian settings, overlooking intermittent drainages that contain potholes that would have been good sources of intermittent water.

The more permanent sites – those that were probably associated with farming activities – are located in the pinyon-juniper woodland near deep soil and intermittent water sources. The more limited activity sites are situated on sandstone outcrops and slickrock expanses covered with thin deposits of eolian sediment. Although these generalizations are valid based on the results of the survey, they should be viewed with caution due to the small size of the sample and because 80% of the sites occurred in one quadrat that had a relatively homogeneous environmental setting.

National Register Recommendations

All of the 166 sites recorded during the project were evaluated according to the National Register Criteria for Evaluation outlined in 36 CFR 60 to determine whether they may be eligible for inclusion on the National Register of Historic Places (NRHP). These criteria have been repeatedly reviewed in the literature and need not be listed here.

The meaning of significance and methods for identifying sites that are eligible for inclusion on the National Register have been the focus of much concern and debate in recent years (Glassow 1977; Schiffer and Gumerman 1977). Tainter and Lucas (1983) argue that this controversy is a result of ambiguity in the eligibility criteria specified in 36 CFR 60. They go on to note that significance is not an inherent attribute "waiting only to be discerned," but a quality assigned by the archeologist. Thus, because significance "is a quality that we assign to a cultural resource based on the theoretical framework within which we happen to be thinking," it will vary between individuals and with changing goals in the profession.

In order to circumvent some of the problems noted by Tainter and Lucas (1983), we identified a series of problem domains which we feel are relevant to a wide range of current and future research on the northern Colorado Plateau. These include chronology, settlement patterns, subsistence patterns and paleoeconomy, demography, affiliation and interrelationships between contemporary cultures, sociopolitical organization, exchange networks and trade, lithic, ceramic and architectural technology and paleoenvironmental reconstruction. Each site was then evaluated according to its potential for substantively contributing to one or more of these problem domains, based on the following criteria: integrity, site size, site type, diversity and density of features and artifacts, the potential for depth and datable materials, cultural affiliation and/or potential for determining affiliation.

Tables 16 through 18 present our recommendations for National Register eligibility. Justifications for these recommendations are included on the individual site forms. Fifty of the 155 sites are considered potentially eligible to the National Register of Historic Places.

Isolated Finds

A total of 274 prehistoric and historic isolated finds were documented in the survey quadrats: 62 in Circle Cliffs, 185 in the San Rafael Swell and 27 in White Canyon. Based on mathematical calculations as discussed for the case of sites in Chapter 7, we project between 321 and 879 prehistoric isolated finds in Circle Cliffs, 1287 and 2053 in the San Rafael Swell, and 27 and 571 in White Canyon. The estimation data for isolated finds are found on tables in Appendix 1.

Tables 19 and 20 summarize the 558 artifacts and features found at the 274 isolated locations. Flakes are the main type of isolated find in all three study tracts, representing 84%, 60% and 67% of the isolated find assemblage in Circle Cliffs, the San Rafael Swell and White Canyon, respectively. Bifaces, the second most frequent type of isolated find in Circle Cliffs and the San Rafael Swell, account for 7% and 12% of the specimens, respectively. Projectile points are the next most common category in these two areas making up 4% and 12% of the collection. Following flakes, points and bifaces are the most common types of isolated find in White Canyon. Other types of prehistoric isolated finds are relatively infrequent and include pottery, ground stone and miscellaneous chipped stone tools. It is noteworthy that the isolated pottery discovered in the Swell occurred on two pot drops, consisting of 15 and 19 sherds each, and in a collector's pile in a historic/recent trash dump.

As a group, the prehistoric isolated finds are indicative of a wide range of tasks, including hunting, plant processing, cooking and/or food storage, core reduction, tool maintenance and stone procurement for flintknapping purposes. The temporal affiliation represented in the assemblage spans the period between the Early Archaic and the Protohistoric with Archaic,

Table 16. List of sites in Circle Cliffs and their eligibility.

Site Number	Eligibility	Site Number	Eligibility
42GA2513	Not eligible	42GA2543	Not eligible
42GA2514	Not eligible	42GA2544	Not eligible
42GA2515	Not eligible	42GA2545	Not eligible
42GA2516	Not eligible	42GA2547	Not eligible
42GA2517	Eligible	42GA2548	Not eligible
42GA2518	Eligible	42GA2549	Not eligible
42GA2519	Not eligible	42GA2550	Not eligible
42GA2520	Not eligible	42GA2551	Not eligible
42GA2523	Not eligible	42GA2552	Eligible
42GA2524	Not eligible	42GA2553	Not eligible
42GA2525	Eligible	42GA2555	Eligible
42GA2526	Not eligible	42GA2556	Not eligible
42GA2527	Not eligible	42GA2558	Not eligible
42GA2528	Not eligible	42GA2559	Eligible
42GA2530	Not eligible	42GA2560	Eligible
42GA2531	Not eligible	42GA2561	Not eligible
42GA2532	Not eligible	42GA2562	Not eligible
42GA2533	Not eligible	42GA2563	Eligible
42GA2534	Not eligible	42GA2564	Eligible
42GA2535	Not eligible	42GA2565	Not eligible
42GA2536	Not eligible	42GA2566	Not eligible
42GA2537	Not eligible	42GA2567	Not eligible
42GA2538	Not eligible	42GA2570	Eligible
42GA2539	Not eligible	42GA2571	Not eligible
42GA2540	Not eligible	42GA2572	Eligible
42GA2541	Not eligible	42GA2573	Not eligible
42GA2542	Not eligible	42GA2574	Eligible

Anasazi, Fremont and Numic cultural affiliations being represented.

The assemblage of historic/recent isolated finds is largely composed of glass fragments and solder dot milk cans, accompanied by a small number of household utensils and features such as hearths and informal walls. These items are indicative of a variety of domestic activities and are probably by-products of herding, mining and perhaps hunting activities.

Table 17. List of sites in the San Rafael Swell and their eligibility.

Site Number	Eligibility	Site Number	Eligibility
42EM1674	Not eligible	42EM1717	Eligible
42EM1675	Not eligible	42EM1718	Eligible
42EM1676	Eligible	42EM1719	Eligible
42EM1677	Eligible	42EM1720	Eligible
42EM1678	Not eligible	42EM1721	Not eligible
42EM1679	Eligible	42EM1722	Eligible
42EM1680	Eligible	42EM1723	Not eligible
42EM1681	Eligible	42EM1724	Not eligible
42EM1682	Not eligible	42EM1725	Not eligible
42EM1683	Not eligible	42EM1726	Not eligible
42EM1684	Not eligible	42EM1727	Eligible
42EM1685	Not eligible	42EM1728	Not eligible
42EM1686	Not eligible	42EM1729	Not eligible
42EM1687	Not eligible	42EM1730	Not eligible
42EM1688	Not eligible	42EM1731	Not eligible
42EM1689	Not eligible	42EM1732	Eligible
42EM1690	Eligible	42EM1733	Not eligible
42EM1691	Not eligible	42EM1734	Not eligible
42EM1692	Not eligible	42EM1735	Not eligible
42EM1693	Not eligible	42EM1736	Not Eligible
42EM1694	Eligible	42EM1737	Not eligible
42EM1695	Not eligible	42EM1738	Not eligible
42EM1696	Eligible	42EM1739	Not eligible
42EM1697	Not eligible	42EM1740	Not eligible
42EM1698	Eligible	42EM1741	Not eligible
42EM1699	Eligible	42EM1742	Not eligible
42EM1700	Not eligible	42EM1743	Not eligible
42EM1704	Not eligible	42EM1744	Not eligible
42EM1705	Eligible	42EM1745	Not eligible
42EM1706	Not eligible	42EM1746	Eligible
42EM1707	Not eligible	42EM1747	Eligible
42EM1708	Not eligible	42EM1748	Not eligible
42EM1709	Not eligible	42EM1749	Eligible
42EM1710	Eligible	42EM1750	Not eligible
42EM1711	Eligible	42EM1751	Not eligible
42EM1712	Eligible	42EM1752	Not eligible
42EM1713	Eligible	42EM1753	Not eligible
42EM1714	Not eligible	42EM1754	Not eligible
42EM1715	Eligible	42EM1755	Not eligible
42EM1716	Eligible	42EM1756	Eligible
		42EM1757	Not eligible

Table18. List of sites in White Canyon and their eligibility.

Site Number	Eligibility	Site Number	Eligibility
42SA14404	Not eligible	42SA14414	Eligible
42SA14405	Eligible	42SA14415	Eligible
42SA14406	Eligible	42SA14416	Not eligible
42SA14407	Eligible	42SA14417	Not eligible
42SA14408	Not eligible	42SA14418	Eligible
42SA14409	Eligible	42SA14419	Not eligible
42SA14410	Eligible	42SA14420	Not eligible
42SA14411	Eligible	42SA14421	Not eligible
42SA14412	Not eligible	42SA14422	Not eligible
42SA14413	Not eligible	42SA14423	Eligible

Table 19. Frequency of prehistoric isolated finds by type and study tract.

Type of Isolated Find	Circle Cliffs	San Rafael Swell	White Canyon	Total
Projectile Points				
Sinbad Side-notched	0	1	0	1
Northern Side-notched	0	0	1	1
Hawken Side-notched	0	1	0	1
Oxbow	0	1	0	1
Gypsum	0	3	0	3
Elko Series	3	4	1	8
Desert Side-notched	0	1	0	1
Large Anasazi corner-notched	0	0	1	1
Indeterminate point	1	31	4	36
Other Chipped Stone Tools				
Biface	7	50	3	60
Drill	1	0	0	1
Uniface	1	0	0	1
Blade	1	0	0	1
Core	0	3	0	3
Flakes				
Decortication flake	1	7	0	8
Primary thinning flake	19	18	4	41
Secondary thinning flake	37	58	20	115
Indeterminate thinning flake	2	5	0	7
Final shaping flake	4	2	1	7
Microflake	3	0	0	3
Indeterminate flake	9	89	0	98
Retouched primary thinning flake	1	1	0	2
Retouched secondary thinning flake	2	1	0	3
Retouched indeterminate flake	2	2	0	4
Test cobbles on a gravel terrace[a]	0	14	0	14
Scattered flakes[a]	0	0	1	1
Shatter	1	10	2	13
Miscellaneous Artifacts				
Mano	1	1	1	3
Metate/grinding slab	0	1	0	1
Sherd	0	41	3	44
Total prehistoric isolated finds	96	345	42	483

[a]Indicates number of occurrences rather than the number of items.

Table 20. Frequency of historic/recent isolated finds by type and study tract.

Type of Isolated Find	Circle Cliffs	San Rafael Swell	White Canyon	Total
Can and glass scatter[a]	0	7	0	7
Solder dot can	8	3	0	11
Crimped seam can	2	0	0	2
Glass bottle	0	5	0	5
Purple glass fragment	0	8	0	8
Other glass fragment	25	0	0	25
Mop	0	1	0	1
Metal lid	1	0	0	1
Wooden spoon	0	1	0	1
Recent petroglyph	0	2	0	2
Milled lumber[a]	0	2	0	2
Wall/structure	1	5	0	6
Hearth	0	2	0	2
Sheep fence	0	2	0	2
Total	37	38	0	75

[a]Indicates number of occurrences rather than the number of items.

Chapter 6

FEATURE AND ARTIFACT DESCRIPTIONS

This chapter contains descriptions of the features and artifacts recorded during the project, as well as functional and temporal interpretations and comparisons where possible. Discussions are also included regarding variations in artifact and feature types and frequencies between and within the three study tracts. Unless otherwise noted, tabulations and discussions only pertain to features and artifacts within the survey quadrats.

Prehistoric Features

A total of 144 features were recorded on 45 prehistoric sites: 10 in Circle Cliffs, 19 in the San Rafael Swell and 16 in White Canyon. Eighteen of the features are located in Circle Cliffs, 61 in the San Rafael Swell and 65 in White Canyon. In order of descending frequency, features discovered during the inventory include hearths, burned/fire cracked rock scatters and concentrations, middens, rock alignments, circular stone structures, rubble mounds, cists, wickiups or windbreaks, masonry structures, pithouses and stone circles. Hearths, burned/fire cracked rock scatters and middens occur in all three areas. Rock alignments, cists and burned/fire cracked rock concentrations are only present in the San Rafael Swell and White Canyon. Features exclusive to a single tract include pithouses in Circle Cliffs, circular stone structures, wickiups/windbreaks and stone circles in the San Rafael Swell, and rubble mounds in White Canyon (Table 21). The type and frequency of features found on each site are listed on a table in Appendix 1.

In addition to the features, six sites in the San Rafael Swell contain subsurface cultural lenses or strata. Four of these are open sites near Tan Seep; the others occur in rockshelters in the northern end of the San Rafael Swell. Subsurface deposits are also present on most of the sites in White Canyon.

Not surprisingly, the frequency of features relative to the amount of acres covered and number of sites recorded is highest in White Canyon where many of the sites seem to have been occupied year-round, or at least for extended periods of time (Table 22). Relative to Circle Cliffs, the San Rafael Swell tract contains a slightly higher percentage of sites with features, and on sites with features, a higher average number of features (Table 22).

Given that features are generally equated with an increase in permanency, it is reasonable to assume that a higher percentage of sites in the San Rafael Swell represent longer term or more intensive utilization than the sites in Circle Cliffs. This difference becomes slightly more pronounced if hearths, a relatively expedient feature, are excluded from the counts. Excluding hearths, the San Rafael Swell has an average of 5.0 features per site on sites with features while Circle Cliffs has an average of only 2.3.

As shown in Table 23, the frequency and diversity of features is highest on the Anasazi sites. Most of the features indicative of high-labor investment and/or long-term occupation, e.g., middens, rubble mounds, cists and masonry structures, are also associated with the Anasazi occupation. Although features are also relatively

Table 21. Frequency of features by type and study tract.

Feature Type	Circle Cliffs	San Rafael Swell	White Canyon	Total
Hearth	11	16	14	41
Burned/fire cracked rock scatter	2	6	17	25
Burned/fire cracked rock concentration	0	13	7	20
Rock alignment	0	9	3	12
Stone circle	0	1	0	1
Circular stone structure	0	10	0	10
Wickiup/windbreak	0	2	0	2
Cist	0	3	4	7
Pithouse	1	0	0	1
Midden	4	1	10	15
Rubble mound	0	0	8	8
Structure	0	0	2	2
Total	18	61	65	144

Table 22. Frequency of features, sites containing features and average number of features per site with features by study tract.

Study Tract	Feature Frequency	Sites with Features		Average Number of Features/Site with Features
		n	%	
Circle Cliffs	18	10	19	1.8
San Rafael Swell	61	19	24	3.2
White Canyon	65	16	80	4.1
Total	144	45	29	3.2

Table 23. Frequency of prehistoric features by cultural affiliation and study tract.

Cultural Affiliation	Hearth	Burned/Fire Cracked Rock Scatter	Burned/Fire Cracked Rock Concentration	Rock Alignment	Stone Circle	Circular Stone Structure	Wickiup/Windbreak	Cist	Pithouse	Midden	Rubble Mound	Masonry Structure	Total
CIRCLE CLIFFS													
Archaic	1	0	0	0	0	0	0	0	0	1	0	0	2
Archaic/ Fremont	0	0	0	0	0	0	0	0	0	0	0	0	0
Archaic/ Anasazi	0	0	0	0	0	0	0	0	0	0	0	0	0
Fremont	0	0	0	0	0	0	0	0	0	0	0	0	0
Anasazi	0	0	0	0	0	0	0	0	0	0	0	0	0
Numic	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Prehistoric	10	2	0	0	0	0	0	0	1	3	0	0	16
Subtotal	11	2	0	0	0	0	0	0	1	4	0	0	18
SAN RAFAEL SWELL													
Archaic	4	1	9	2	0	3	2	0	0	1	0	0	22
Archaic/ Fremont	6	0	0	0	0	0	0	0	0	0	0	0	6
Archaic/ Anasazi	0	0	0	0	0	0	0	0	0	0	0	0	0
Fremont	1	1	1	2	0	0	0	0	0	0	0	0	5
Anasazi	0	0	0	0	0	0	0	0	0	0	0	0	0
Numic	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Prehistoric	5	4	3	5	1	7	0	3	0	0	0	0	28
Subtotal	16	6	13	9	1	10	2	3	0	1	0	0	61
WHITE CANYON													
Archaic	0	0	0	0	0	0	0	0	0	0	0	0	0
Archaic/ Fremont	0	0	0	0	0	0	0	0	0	0	0	0	0
Archaic/ Anasazi	0	1	0	0	0	0	0	0	0	2	0	0	3
Fremont	0	0	0	0	0	0	0	0	0	0	0	0	0
Anasazi	13	15	7	3	0	0	0	4	0	8	8	2	60
Numic	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Prehistoric	1	1	0	0	0	0	0	0	0	0	0	0	2
Subtotal	14	17	7	3	0	0	0	4	0	10	8	2	65
Total	41	25	20	12	1	10	2	7	1	15	8	2	144

common on Archaic sites, they represent a lower expenditure of labor and more ephemeral, short-term use. No features were observed on sites of Numic affiliation.

Hearths

Hearths, the most common type of feature discovered during the survey, are characterized by concentrations of charcoal and/or ash. They are often accompanied by fire cracked, burned or oxidized sandstone. With the exception of four slab-lined hearths in White Canyon and one in Circle Cliffs, none exhibit evidence of preparation other than the excavation of a small, shallow pit. In general, the hearths appear to represent informal, short-term, surface fires used for cooking, heating and lighting.

The hearths are usually circular to oval in plan and range from 0.5 to 4.0 m in diameter, with most being about a meter across. Limited probing revealed that one hearth contained over 25 cm of fill; more commonly, the hearths have only 2 to 4 cm of deposits.

The slab-lined fire pits in White Canyon are characterized by dark ashy stains encircled by upright or partially upright sandstone slabs and blocks. A similar feature was noted in the center of a pithouse (site 42GA2557) located outside of a survey quadrat in Circle Cliffs. Slab-lined hearths are relatively common in southeastern Utah (Brown 1983; Haase 1983); hearths, in general, are common on sites near all three of the study tracts (Berge 1974; Kearns 1982).

The frequency of hearths on sites with hearths ranges from one to two in Circle Cliffs, one to six in the San Rafael Swell and one to three in White Canyon. There is an average of 1.6 hearths per site with hearths in both Circle Cliffs and the San Rafael Swell, and 1.8 in White Canyon. Hearths were found on one Late Archaic site and six sites of unknown affiliation in Circle Cliffs. In the San Rafael Swell, hearths were present on three Early Archaic, one Late Archaic, one Middle Archaic/Fremont and one Fremont site, and three sites of unknown affiliation. All but one of the hearths in White Canyon occur on Anasazi sites of Pueblo II-III age.

Burned/Fire Cracked Rock Scatters

Burned rock scatters consist of small pieces of oxidized, burned and/or fire cracked stone, usually sandstone, dispersed across a site. In Circle Cliffs and the San Rafael Swell, these features frequently occur in rockshelter sites and consist of burned stone strewn across the site's surface. In White Canyon, burned stone is often scattered in middens and rubble mounds. Burned stone scatters are most common on Anasazi sites but occur in low frequencies on Archaic and Fremont sites (Table 23).

Burned/Fire Cracked Rock Concentrations

Features designated as burned/fire cracked rock concentrations consist of burned, oxidized and/or fire cracked rock in discrete concentrations. They do not exhibit charcoal or ash on the surface or in limited subsurface probes. Similar features containing ash and/or charcoal were considered hearths or middens, as appropriate. The concentrations are typically circular to oval in plan and range from 0.7 to 10.0 m in diameter. The fire cracked, burned or oxidized stones are generally less than 0.2 m across. In the San Rafael Swell, fire cracked rock concentrations occur on one Late Archaic site, one Fremont site and two sites of indeterminate affiliation. Seven of the Anasazi sites in White Canyon exhibit such features.

The Late Archaic site, site 42EM1698, a base camp located in the San Rafael Swell, contains nine concentrations of fire cracked sandstone ranging from 0.9 to 3.5 m in diameter. Although none exhibit ash or charcoal on or just below the surface, ash and charcoal could be more deeply buried; these features may be the remains of roasting ovens, heat treatment pits or hearths.

Rock Alignments

Different types of rock alignments occur in several different settings in the San Rafael Swell and White Canyon study tracts. In the San Rafael Swell, most are alignments of small- to medium-sized local sandstone and limestone slabs and boulders abutted to the back wall of shallow overhangs. They are typically dry-laid, one to three courses high, and 1 to 2 m long. In several cases, there is evidence that two or more alignments were originally connected forming a small structure. The other type of alignment noted in the Swell consists of large, unshaped, limestone blocks stacked several courses high to form a wall. These alignments range from 3.5 to 5.8 m long and 0.6 to 0.8 m high. They are identical to the second type of circular stone structure discussed below, except that one side is open or unfinished. Rock alignments are common throughout the Fremont area (Madsen 1975a).

In White Canyon, alignments of sandstone blocks are visible within a rubble mound and on the surface of a small sherd and lithic scatter. The former appear to be walls of buried habitation or storage structures. The function of the other alignment, a semicircle of oxidized stones, is unknown. The rock alignments in White Canyon occur in an Anasazi context. Those in the Swell occur with both Fremont and Archaic materials.

Stone Circles

The only stone circle found during the project is associated with an extensive lithic scatter (site 42EM1736) situated on Rattlesnake Bench in the northern portion of the San Rafael Swell. The circle consists of unshaped, eroded limestone slabs and boulders arranged in a circle measuring roughly 4 m in diameter. The feature rests on an eroded limestone substrate with no possibility for depth. Stones range from small to very large and are from 0 to 60 cm apart. The circle is open to the northwest.

The large size of the stones comprising this feature implies that it is not a tipi ring (cf. Aikens 1967), especially because smaller stones are available nearby. The absence of interior features suggests that it is not a surface "pit dwelling" as defined by Madsen (1975a), although evidence of a floor or fire pit could have been destroyed by weathering. Interpretation of such features will have to await additional investigation and expansion of the comparative data base.

Circular Stone Structures

Two types of circular stone structures were found on two different sites in the northern end of the San Rafael Swell. The first type consists of a "slab-lined stone circle," perhaps better described as a circle of partially upright large sandstone slabs, surrounded and supported by other blocks and slabs on the exterior side (Figure 17). These structures are made from unshaped sandstone slabs and blocks measuring up to a meter across, and they exhibit no evidence of mortar. They are roughly 5 m in diameter and 0.5 m high. All are situated on an eroding sandstone substrate and none appear to have interior features. All seven examples of this structure type were found at site 42EM1732, a base camp of indeterminate affiliation situated on a bedrock outcrop overlooking the San Rafael River.

The second type of structure is a circular enclosure of irregular, unshaped limestone blocks unevenly stacked to form a wall ranging from one to three courses high. These features range from 1.0 to 3.5 m across and 0.5 to 1.0 m high (Figure 18). None exhibit mortar or interior features, and all are situated on bedrock. They are constructed of large, extremely heavy stones measuring roughly 0.6 m long, 0.5 m wide and 0.3 m thick. This type of structure was recorded on site 42EM1756, a Late Archaic base camp overlooking Black Dragon Canyon.

Although common in Fremont sites (Madsen 1975a; Schroedl and Hogan 1975; Taylor 1957; Wilson and Smith 1976), the function of circular stone surface structures is apparently unknown. Madsen (1975a:25) notes that these "...curious arrangements of rocks in circular or square patterns which lack evidence of floors, postholes or fire basins [are] always enigmatic." Aside from the absence of interior features, the slab-lined structures at site 42EM1732 resemble other slab-lined surface dwellings found among the San Rafael Fremont (Aikens 1967). It is possible that these structures may have once contained interior features.

Another explanation is that the structures are hunting blinds (cf. Binford 1983): all are located on the edge of bedrock eminences with an excellent view of the surrounding terrain and all

Figure 17. One of five slab-lined circular stone structures on an eminence overlooking the San Rafael River.

offer concealment from game in the drainage below. The rock alignments accompanying the circular stone structures on site 42EM1756 are also positioned so that they offer concealment (Figure 19). Gillin (1955:24) believes a similar site in an analogous topographic setting in Nine Mile Canyon is a lookout.

Wickiups or Windbreaks

Two of the fire cracked rock concentrations noted on a Late Archaic base camp in the San Rafael Swell, site 42EM1698, are surrounded by low piles of juniper boughs which are evidently wickiups or windbreaks. The juniper encirclements are roughly 4 m in diameter whereas the fire cracked rock concentrations within the boughs measure only 2.3 and 2.6 m across. An informal mealing bin is also adjacent to one of the rock concentrations.

Because it is difficult to demonstrate whether the boughs are contemporaneous with the fire cracked rock concentrations and/or the mealing bin, interpretation of these features can only be speculative. They may be windbreaks that sheltered plant processing and/or cooking activities, or the remnants of temporary shelters similar to Southern Paiute wickiups (Euler 1966:26).

Cists

Five slab-lined and two masonry cists were discovered on five sites during the project. The masonry cists and one slab-lined cist were found on two sites of unknown affiliation in Oil Well Draw in the northern end of the San Rafael Swell. The remaining features occurred on Pueblo habitation sites in the White Canyon study tract (Table 23). The masonry cists were discovered in a shallow overhang, site 42EM1720, and consist of semicircular walls abutted to the back wall of the shelter. They are built of mortar, sandstone cobbles measuring from 10 to 25 cm across and sticks measuring 1.0 to 1.5 cm in diameter. The cists are roughly

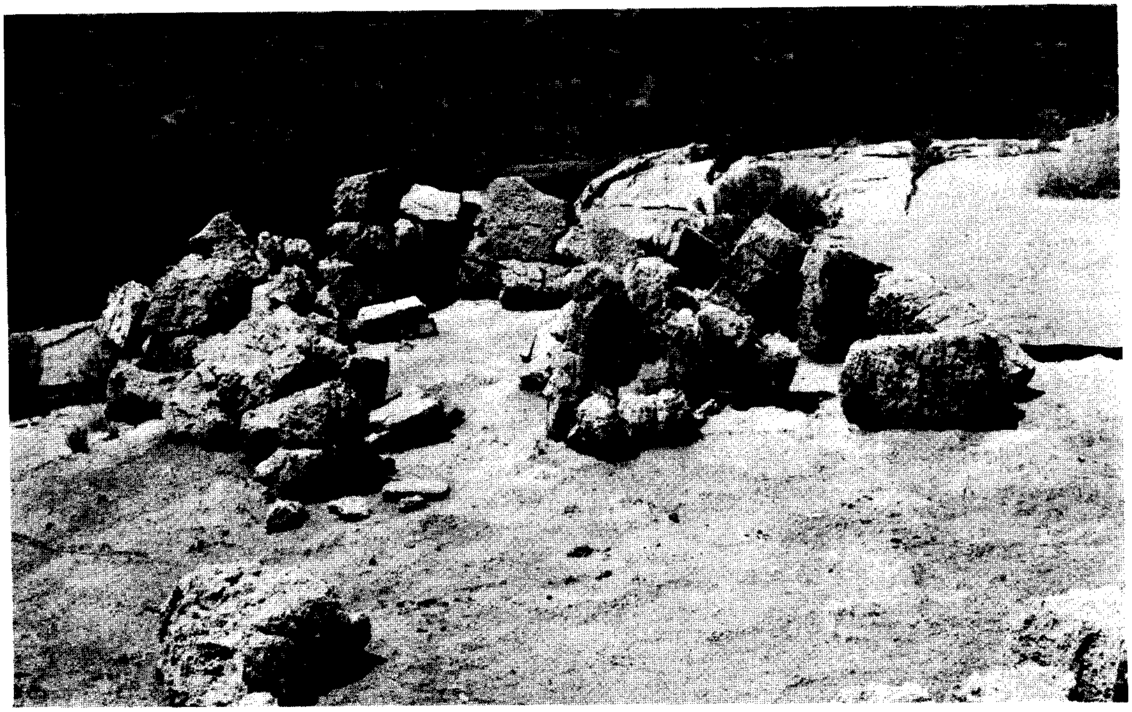

Figure 18. Circular stone structure on a point overlooking Black Dragon Canyon.

1.0 m across, 0.5 m deep and one course high. Small wet-laid masonry structures and cists are common in overhangs and rockshelters throughout the Fremont area, particularly in the San Rafael Fremont area. Like those in Oil Well Draw, they are often wet-laid and abutted to the back wall of small shelters (Gunnerson 1969:149; Marwitt 1970:53, 145).

Another cist in the San Rafael Swell consists of a circular arrangement of limestone slabs propped upright on a bedrock outcrop by small irregular cobbles. The cist is roughly 1 m in diameter and evidently dry-laid. Although slab-lined cists are common in the San Rafael Fremont area (Gunnerson 1969; Madsen 1975a), the open location of this feature is rather unusual.

The White Canyon cists are circular to oval in plan, lined with sandstone slabs, and 0.7 to 1.0 m in diameter. They are typically constructed of 10 or less slabs which measure from 0.3 to 1.0 m long (Figure 20). Slab-lined cists are common on Pueblo sites throughout southeastern Utah (Brown 1983; Lipe 1967a; Sargent 1979) and are usually interpreted as evidence of food storage.

Pithouses

Three buried pithouses were discovered in road cuts in two separate locations in Circle Cliffs. Both sites are situated in an open rolling valley near tributaries to the North Fork of Silver Falls Creek. One of the sites, site 42GA2557, has two pithouses and is located outside the survey quadrats. It is discussed in this section because of its importance to the prehistory of the area. The other site, site 42GA2570, contains a single pithouse associated with a lens interpreted as a hearth and another small, dark stain.

The pithouse at site 42GA2570 is located 0.5 m below the modern surface and is characterized by a saucer-shaped charcoal and ash lens, 3.5 m long and 0.3 m thick. Several flakes were discovered in the profile of the lens. No pottery was found at the site, despite a concerted search.

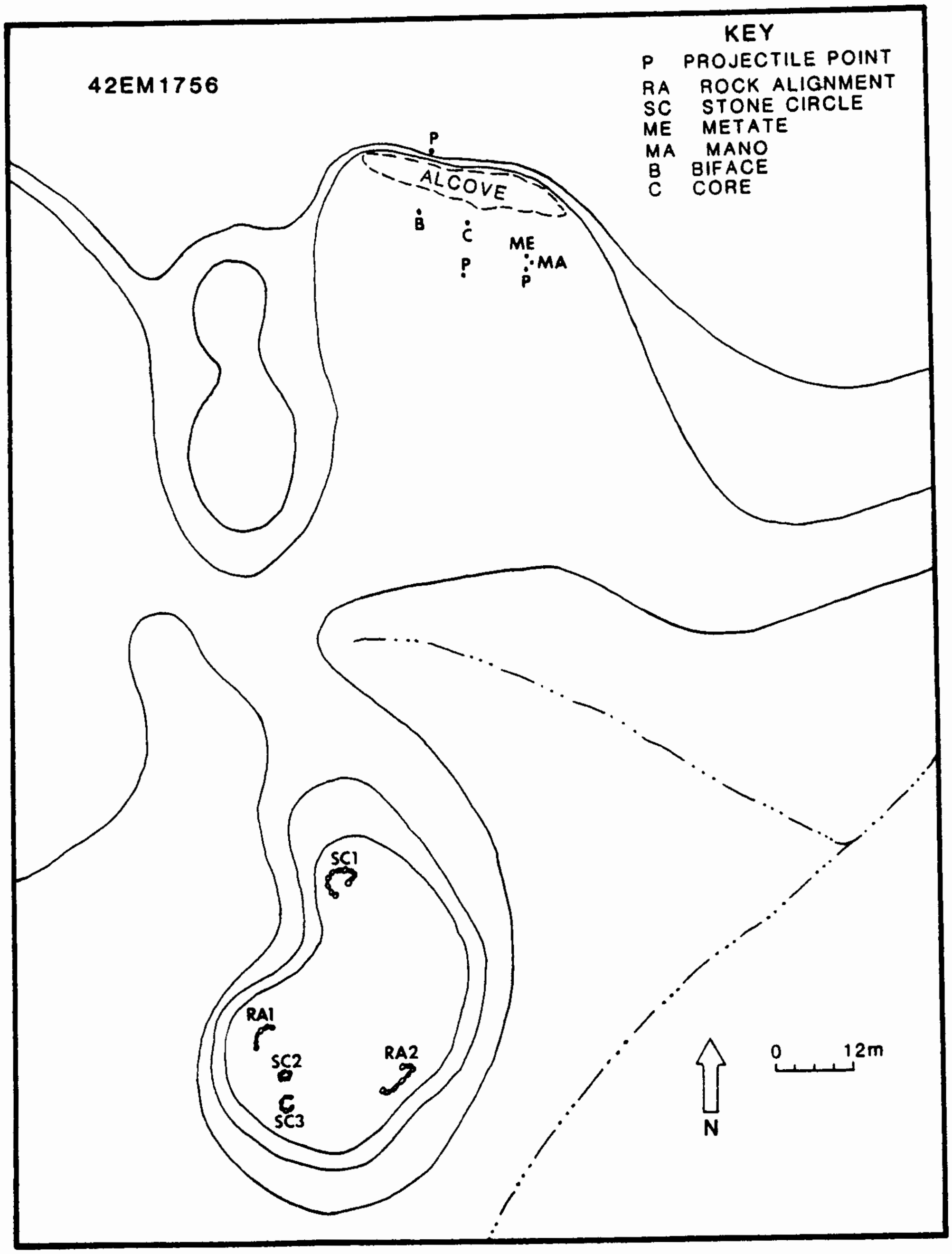

Figure 19. Map of site 42EM1756 showing rock alignments and circular stone structures on a point overlooking Black Dragon Canyon in the San Rafael Swell.

Site 42GA2557, located several kilometers north of site 42GA2570, contains two large ash lenses, interpreted as pithouses, and a small ash stain which may be a midden. No pottery and only a few artifacts are present on the modern surface above the buried features. One pithouse

Figure 20. Slab-lined cist in the White Canyon study tract.

is evidenced by an ash and charcoal stain measuring 3.5 m long and 5 to 10 cm thick. A concentration of sandstone slabs near the center of this stain appears to be a slab-lined hearth. The presence of a hearth in the road cut suggests that this feature was bisected near its center and that the length of the stain is very close to the actual diameter of the structure.

The second pithouse is evidenced by a saucer-shaped ash and charcoal lens, 4.2 m long with an average thickness of 10 cm (Figure 21). A layer of oxidized sand, measuring about 70 cm long and 5 cm thick, occurs along the bottom of the lens. Because of the potential importance of this site type, P-III Associates submitted a radiocarbon sample from the charcoal lens. This sample has an age of 1700 ± 60 years:A.D. 250 (Beta 7705). The tree-ring corrected equivalent is A.D. 185, with a 95% confidence interval of A.D. 80 to 450 (cf. Klein et al. 1982).

This date is clearly within the time range of several other early pithouse sites in southern Utah and northern Arizona. Berry (1982) discusses most of these and other more distant pithouse sites and concludes that pithouses predating A.D. 700 in the Anasazi area can be subdivided into three chronological stages: 185 B.C. to A.D. 1, A.D. 200 to 370 and A.D. 600 to 700. The dated pithouse at site 42GA2557 lies in the middle group, a group that includes all of the other sites in southern Utah and northern Arizona: the Little Jug Site (Berry 1982:55; Thompson and Thompson 1974), Lone Tree Dune (Sharrock et al. 1963), site 42SA6284 (Sargent 1979), and the Pittman and Veres sites on Cedar Mesa (Berry 1982:57). The pithouses at these sites are typically circular to oval in plan and range from 3.0 to 7.0 m across. Most have a lateral entry way, a central hearth and evidence of a superstructure. Except for the Little Jug site and site 42SA6284, none were associated with pottery.

Berry (1982:88) believes that these sites, and others with similar dates in New Mexico, Arizona and Colorado, represent classic Basketmaker II occupation, even though a number contain plain gray ware pottery. While we do not refute his conclusions, we do believe that

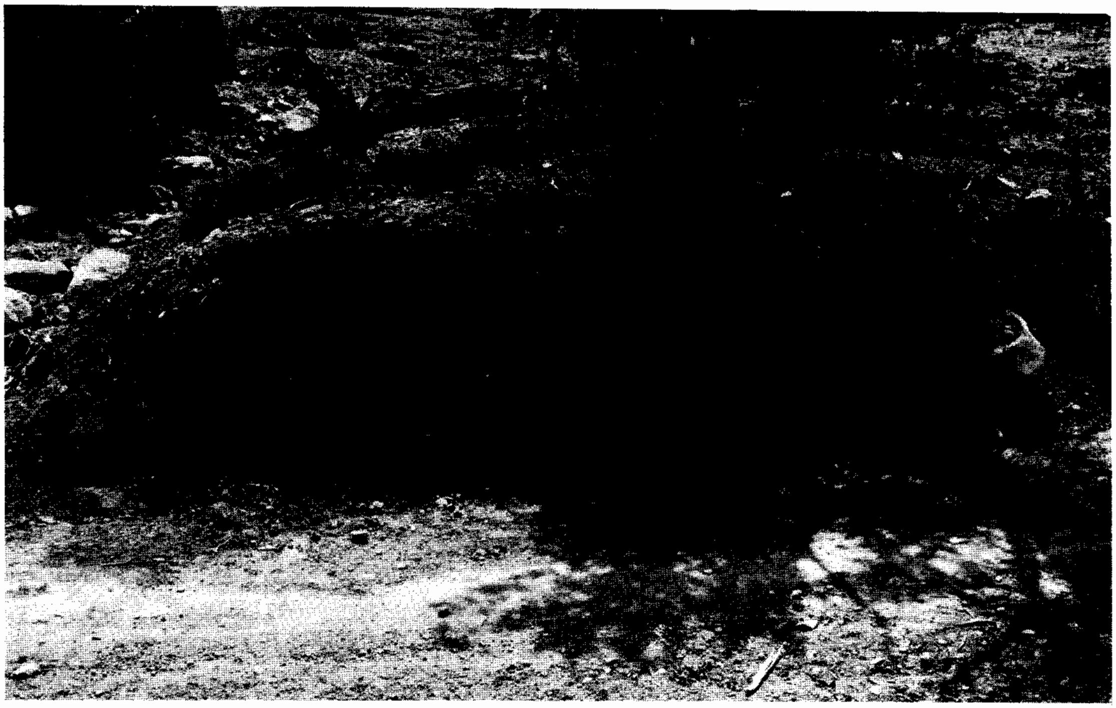

Figure 21. Profile of a pithouse at site 42GA2557 in a road cut in Circle Cliffs.

they should be carefully evaluated when considering the more northerly pithouses such as those in Circle Cliffs. Although located in the general Anasazi area, these pithouses may represent Archaic or even Fremont occupation.

Numerous Archaic period pithouses, some more than 4000 years old, have been found in recent excavations throughout the western United States (Ames and Marshall 1980; Euler and Stiger 1981; Frison 1978; Wheeler and Martin 1982). Excavations at Cowboy Cave (Jennings 1980), in the vicinity of the project area, revealed that the Archaic inhabitants excavated saucer-shaped depressions in the sterile fill near the sides of the cave (Alan Schroedl, personal communication). These depressions had centrally located hearths, measured about 3 m in diameter and were cleared of debris regularly. The debris was piled near the center of the cave causing windrows that were clearly visible during the excavations.

Thus, the pithouses in Circle Cliffs could represent Archaic, Anasazi or even Fremont occupation. Resolution of this problem will clearly have to await further investigations and excavations.

Middens

Fifteen middens were discovered on 13 sites during the project. Four occur on base camps in Circle Cliffs; one was found on an Early Archaic base camp in the San Rafael Swell. The remaining 10 middens were noted on 7 Pueblo habitation sites and 1 Middle Archaic/Pueblo base camp in White Canyon.

Two of the "middens" in Circle Cliffs are circular to oval stains which may be pithouses similar to those described above. Both are located on the sandstone bench below Big Bown Bench adjacent to low, shallow overhangs. One of these features, located on site 42GA2563, contains dark soil, fire cracked rock, oxidized sandstone and lithic debitage. It measures 4.5 by 3.7 m and is over 15 cm deep. The other feature is located on site 42GA2564 and consists of dark ashy soil intermixed with oxidized sandstone, charcoal and a variety of artifacts. This feature is 6.5 by 8.5 m across and is over 20 cm deep in the center. It is shallower near the edges, indicating that the feature is slightly saucer shaped. Neither of these sites is currently identifiable to age or cultural affiliation.

The other two sites in Circle Cliffs containing middens, sites 42GA2572 and 42GA2574, are located near the Silver Falls drainage and Horse Pasture Mesa, respectively. The midden at site 42GA2572 consists of a circular stain exhibiting ash, charcoal and oxidized sandstone. Adjacent to a shallow overhang, it is 2.5 m in diameter and 7 to 25 cm deep. The midden at site 42GA2574, a Late Archaic base camp, measures roughly 2 by 4 m and consists of ash, sand and debris to a depth of 10 cm. The function of these features is unknown, although they may be the remains of semisubterranean structures such as the pithouses noted above, or simply areas where refuse was discarded. The age, function and affiliation of these features requires further investigation.

The middens in White Canyon typically consist of ash and charcoal, fire cracked, burned and oxidized sandstone, burned soil and a variety of artifacts. Based on surface indications, they range from oval to circular to crescentic in shape and measure from 2 by 3 m to 9 by 19 m. Over half occur on sites with rubble mounds—which they border on the east, southeast, west and southwest sides (Figure 22). Several of the "middens" may be the remains of buried structures. Most, however, represent areas where trash was discarded away from the living areas.

Rubble Mounds and Structures

Nine rubble mounds were recorded on six Puebloan habitation sites in the White Canyon tract. They generally consist of unshaped sandstone blocks, slabs and spalls, often fire reddened, that are exposed on the surface forming a low mound. Some occur as discrete, dense concentrations, while others are evidenced by a less dense continuous scatter. The rubble mounds range from 3 by 6 m to 7 by 7 m. Two of these clearly represent in-situ masonry roomblocks containing two and possibly four rooms each. Visible within another mound is the perimeter of a square roomblock, 5.25 m long on a side. A standing, dry-laid wall constitutes a portion of one side of this roomblock (Figure 22).

Comparisons

It is difficult to ascertain whether the features discovered during this inventory are representative or typical of the area; nearby excavation projects have primarily focused on habitation sites rather than limited activity sites such as those found in the respective study tracts (Aikens 1967; Fowler 1963; Lister and Lister 1961; Schroedl and Hogan 1975; Taylor 1957). Reports on nearby surveys—which have included more ephemeral sites—rarely describe or tabulate any features that were found.

Hearths were the most common type of feature discovered on the Escalante Project near the Circle Cliffs tract. The frequency of hearths and number and affiliation of sites with hearths is not reported, however. Other features were apparently discovered, but none are discussed or quantified in the report (Kearns 1982). The absence of substantial features such as masonry architecture contrasts with surrounding areas, but is not surprising given the marginal environmental setting of the study tract.

Four sites with hearths were recorded during the Central Coal II survey near the San Rafael Swell, but it is not known if other features were found (Thomas et al. 1981). The low frequency of hearths is somewhat surprising given their relative abundance in the San Rafael Swell study tract and the nearby Castle Valley (Berge 1974). Comparisons with excavated sites reveal some similarities with San Rafael Fremont storage and habitation facilities (Aikens 1967; Madsen 1975a; Schroedl and Hogan 1975; Taylor 1957; Wilson and Smith 1976), although the features discovered in the study tract seem to represent more ephemeral and opportunistic use. Features discovered in the White Canyon tract are typical for the area (Lucius 1979; Nickens 1982).

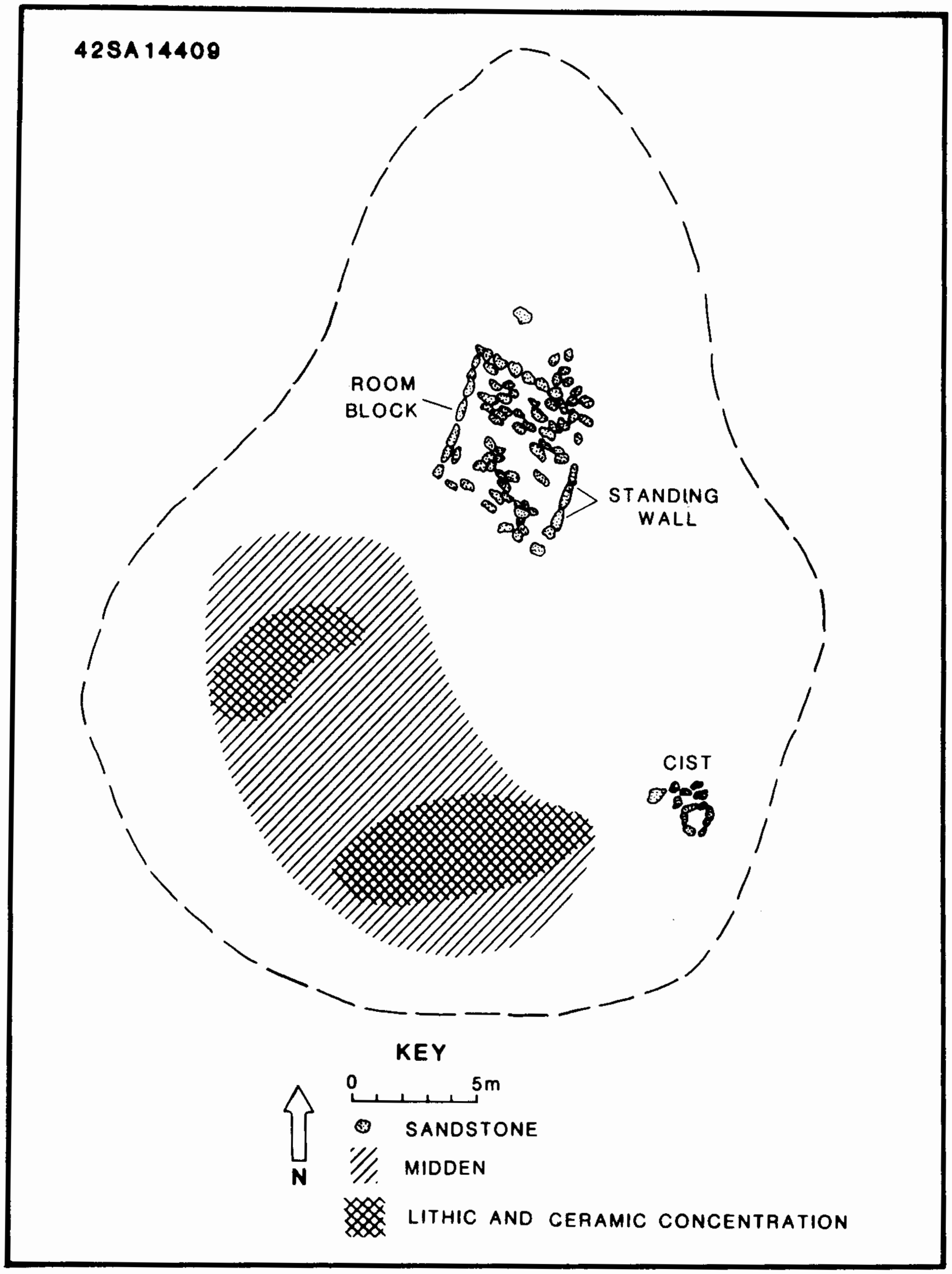

Figure 22. Map of site 42SA14409 showing the roomblock/rubble mound, midden and a small slab-lined cist.

Artifacts

Several broad categories of artifacts were discovered during the survey including pottery, chipped, pecked and ground stone, and perishable materials. The total assemblage encompasses about 1000 chipped stone tools, 50,000 pieces of debitage, 90 ground and pecked stone artifacts, 880 sherds and a small number of perishable artifacts. A wide variety of

Euroamerican materials were also noted including glass, tin cans, kitchen utensils and car parts. The prehistoric artifacts and historic artifacts that are more than 50 years old are discussed in the sections below. In these discussions, the artifacts have been segregated into traditional artifact classes, most based on morphological criteria. These categories are used to facilitate description and comparisons to other assemblages and are not meant to imply function unless otherwise noted.

Chipped Stone Artifacts

Projectile Points

With the exception of limited amounts of pottery, projectile points are the most time-sensitive group of artifacts recovered during the project. They can often be used to establish tentative temporal and cultural affiliations and may be useful in identifying cultural boundaries and trade networks. They are especially valuable for survey projects because, as surface evidence, they can provide chronological information for sites that cannot be dated by other means.

A total of 302 whole and fragmentary projectile points was recorded during the inventory: 63 in Circle Cliffs, 208 in the San Rafael Swell and 31 in White Canyon. One hundred and seventy-three of these were collected for further analysis. The 302 specimens represent 19 named types, including two new types, and eight categories of indeterminate points (Table 24). The tentatively identified new point types, Sinbad Side-notched and San Rafael Stemmed, provisionally date to the Archaic period. In addition, eight points representing contact, influence or trade with the Northwestern Plains were identified in Circle Cliffs and the San Rafael Swell. These types, Hawken Side-notched, Mount Albion Corner-notched, Oxbow and McKean Lanceolate, date to the Archaic period.

For a point typology to be useful in the tasks noted in the introductory remarks, the types must be well defined and based on objective criteria so that the classifications can be replicated by other archeologists. A variety of multivariate techniques have been used to this end, such as cluster, factor and discriminant analysis (Calabrese 1973; Gunn and Prewitt 1975; Holmer 1978; Lucterhand 1970). Of these multivariate techniques, discriminant analysis has been the most successful because it can be used to establish a set of linear classification functions which statistically differentiate between independent types. These functions can then be used to segregate untyped specimens into the existing statistical typology (Klecka 1980).

Holmer (1978) conducted such an analysis for Archaic point types on the northern Colorado Plateau. In his study, classification functions were developed using specimens from the original type sites and refined using the point assemblage from Sudden Shelter (Jennings et al. 1980). The classification functions were then applied to points from Hogup (Aikens 1970), Danger (Jennings 1957) and Cowboy (Jennings 1980) caves with a correct classification rate of 95% (Holmer 1978:21).

In order to provide statistically defensible classifications, the points recovered during the project were classified according to the procedures and discriminant functions developed by Holmer (1978). This involved measuring or digitizing the x and y coordinates of seven locations around the perimeter of each point to the nearest millimeter, as shown in Figure 23. These data were then entered into a computer program which calculates the 13 variables – 7 distance and 6 angle measurements – used in Holmer's discriminant analysis (Table 25). Although the 13 measurements can be taken directly from the artifacts, it is easier and more consistent to calculate them from the coordinates of the seven key locations. These variables were then entered into the discriminant program which calculated classification scores for each point and the probability of it belonging to each type. Points were then assigned to the type in which they had the highest probability of membership.

Following Holmer (1978), fragmentary specimens were excluded from the analysis when coordinate points 1-5 (see Figure 23) were lacking because the discriminant functions are primarily based on differences in the base and

Table 24. Frequency and distribution of projectile points by type and study tract.

Projectile Point Type	Circle Cliffs	San Rafael Swell	White Canyon	Total
Lake Mohave	0	1	0	1
Pinto Series	1	11	0	12
Sinbad Side-notched	0	3	0	3
Humboldt Concave Base	0	2	0	2
Northern Side-notched	0	0	1	1
Rocker Side-notched	0	0	1	1
Hawken Side-notched	2	2	0	4
Sudden Side-notched	2	1	0	3
Mt. Albion Corner-notched	1	0	0	1
Oxbow	0	2	0	2
McKean Lanceolate	1	0	0	1
San Rafael Side-notched	1	3	1	5
Gypsum	5	11	0	16
San Rafael Stemmed	2	3	0	5
Elko Series	20	49	1	70
Rose Spring	3	0	0	3
Nawthis Side-notched	0	1	0	1
Bull Creek	0	0	2	2
Desert Side-notched	1	3	0	4
Small Anasazi corner-notched	0	0	3	3
Small Anasazi side-notched	0	0	2	2
Large Anasazi corner-notched	0	0	2	2
Indeterminate medium, stemmed	0	3	0	3
Indeterminate stemmed	2	3	1	6
Indeterminate small, triangular	1	1	1	3
Indeterminate leaf-shaped	0	1	0	1
Indeterminate	21	108	16	145
Total	63	208	31	302

haft element. Only a few points had to be discarded, however, because incomplete points were not collected when they appeared too fragmentary to be identifiable.

For descriptive purposes, the distance and angle measurements were calculated for the arrow points, Anasazi points and point types not included in Holmer's original analysis (e.g., Oxbow and Mt. Albion Corner-notched). These data were not subjected to the discriminant analysis, however, because the classification functions distinguishing these types have yet to be developed. If they had been included, they would have been classified to the most similar point type, but they would have had an extremely low probability of actually belonging to that group. These points were classified in a traditional manner using descriptions available in Benedict and Olson (1978), Holmer and Weder (1980), Millar (1978) and the IMACS User's Guide.

Following the initial analysis, visual examinations and evaluations of group membership probabilities allowed us to isolate eight points which are thought to represent two previously unidentified Archaic point types. Although the autonomy of these two types was verified through additional runs and statistical comparisons with the measurements of known types provided by Holmer, they are considered

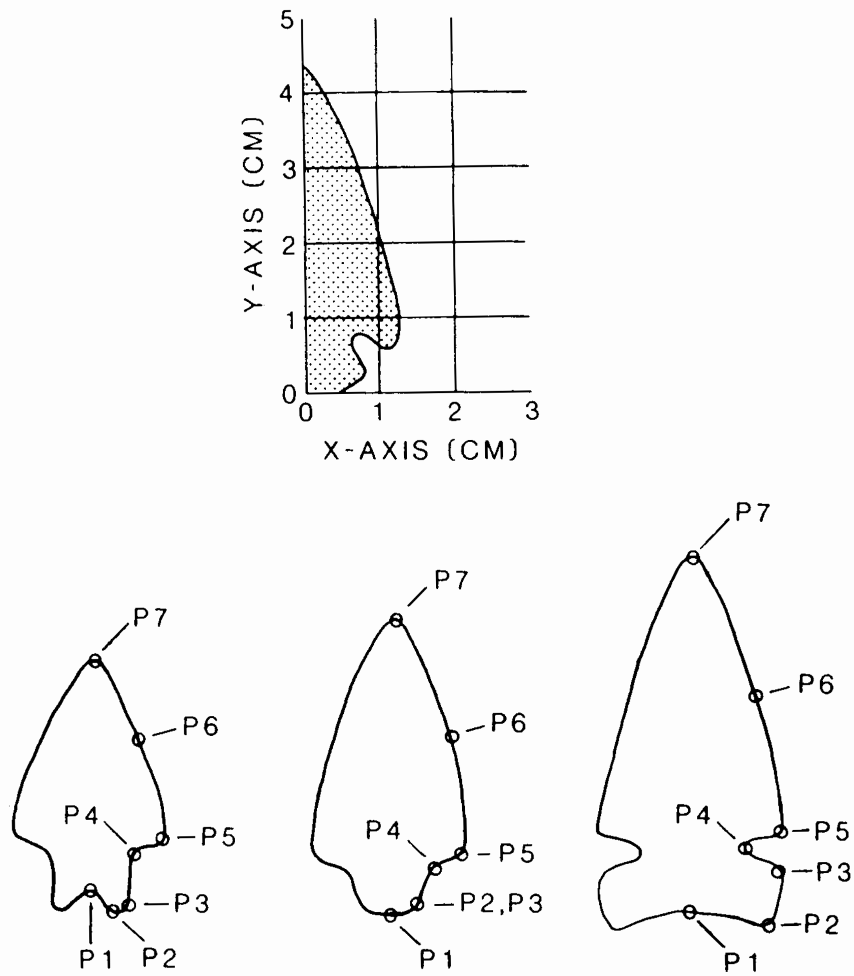

Figure 23. Example of the coordinate system and the location of digitized coordinate points (ADAPTED FROM: Holmer 1978:7).

tentative pending the discovery of additional specimens. The two provisional types, Sinbad Side-notched and San Rafael Stemmed, are named after prominent geographical features in the San Rafael Swell study tract.

Following the format established by Holmer (1978), Table 26 presents the average distance and angle measurements for each point type except the unknown category. Tables in Appendix 1 show the frequency and type of points on each site.

Lake Mohave

One point classified as a Lake Mohave point (cf. Campbell and Campbell 1937) was recovered from site 42EM1748 in the San Rafael Swell (Figure 24a). This slightly shouldered fragment has a contracting stem and is made from tan siltstone. Lake Mohave points are rare on the northern Colorado Plateau but are reported to predate 8500 B.P. in the Great Basin (Hester and Heizer 1973).

Pinto Series

This category includes 12 whole and fragmentary points which are characterized by large, triangular blades with concave to convex margins and decidedly notched bases (Figure 24b-e). One is stemmed and appears to be a Pinto Shoulderless (cf. Amsden 1935; Holmer 1978).

Table 25. Variables used in discriminant analysis of projectile points.

Variable	Measurement
M1	Distance from P1 to P2 (in millimeters)
M2	Distance from P2 to P3 (in millimeters)
M3	Distance from P3 to P4 (in millimeters)
M4	Distance from P4 to P5 (in millimeters)
M5	Distance from P3 to P5 (in millimeters)
M6	Length of point (in millimeters)
M7	Width of point (in millimeters)
A1	Angle from P1 to P2 (measured from horizontal)
A2	Angle from P2 to P3 (measured from horizontal)
A3	Angle from P4 to P3 (measured from horizontal)
A4	Angle from P4 to P5 (measured from horizontal)
A5	Angle from P3 to P5 (measured from horizontal)
A6	Sum of A3, A4 and A5

SOURCE: Holmer 1978:9.

The others have side or corner notches which form sloping shoulders.

Pinto points range between 8300 and 6200 B.P. at Cowboy Cave, Sudden Shelter and Joe's Valley Alcove on the northern Colorado Plateau (Holmer 1978), but are later in the Great Basin (Fowler et al. 1973). Of the 12 Pinto points recovered during the survey, 11 were found in the San Rafael Swell; only one was discovered in Circle Cliffs (Table 24). Eight are made from chert; the others are made from tan chalcedony and gray quartzite.

Sinbad Side-notched

Sinbad Side-notched, tentatively defined as a result of the discriminant analysis, is a small, short, lanceolate point with convex blade margins, very shallow side notches and a straight to slightly concave base (Figure 24f-h). It is biconvex in cross section and thick relative to its overall size. Average distance and angle measurements are provided in Table 26.

Three Sinbad Side-notched points were recovered during the project, all of them near Sids Draw in Sinbad Country of the San Rafael Swell. Two are made from gray chert; the other is made from purple chert. Sinbad Side-notched points occur with Pinto, Humboldt and San Rafael Side-notched points and appear, based on this scanty surface evidence, to date to the Early Archaic period.

Humboldt Concave Base

Two specimens identifiable as Humboldt points (cf. Heizer and Clewlow 1968) were discovered on site 42EM1747 in the San Rafael Swell (Figure 24i-j). Both are characterized by large, lanceolate blades with convex margins. Material types include gray quartzite and light purple chert. Humboldt Concave Base points have been dated to between 7600 and 6100 B.P. on the northern Colorado Plateau (Holmer 1978), but they occur in later contexts in the Great Basin, circa 5500 to 3800 B.P. (Fowler et al. 1973). They are also reported in Fremont contexts (Dalley 1976).

Northern Side-notched

A single Northern Side-notched point (cf. Gruhn 1961) was recovered as an isolated find in the White Canyon study tract. It is made of brown chert and has been almost completely reworked into a scraper. Northern Side-notched points have a relatively short time span on the northern Colorado Plateau, circa 6900 to 6300 B.P., and are considered to represent the Early Archaic period (Holmer 1978). Similar points

Table 26. Mean distance and angle measurements for selected projectile points recovered during the project.

Point Type	Measurements						
	M1	M2	M3	M4	M5	M6	M7
Lake Mohave	.51	.00	1.96	.14	2.09	n/a	2.20
Pinto Series	.47	.32	.57	.53	5.79	5.00	2.00
Sinbad Side-notched	.47	.09	.41	.23	.61	n/a	1.13
Humboldt Concave Base	.51	.07	n/a	n/a	n/a	n/a	n/a
Northern Side-notched	1.02	.90	.36	.32	.30	n/a	2.00
Rocker Side-notched	1.22	.41	.41	.36	.63	n/a	2.20
Hawken Side-notched	.90	.33	.40	.45	.66	n/a	1.90
Sudden Side-notched	1.07	1.41	.52	.27	.60	n/a	2.40
Mount Albion Corner-notched	.71	.00	.61	.22	.76	3.50	2.00
Oxbow	1.05	.75	.65	.29	.76	n/a	2.20
McKean Lanceolate	.71	.00	.71	.54	1.20	n/a	1.60
San Rafael Side-notched	1.12	.93	.41	.33	.52	n/a	2.00
Gypsum	.39	.03	.46	.43	.78	3.49	1.85
San Rafael Stemmed	.74	.02	.98	.39	1.06	n/a	2.27
Elko Eared	.62	.34	.54	.48	.61	3.00	1.97
Elko Corner- and Side-notched	.73	.22	.53	.47	.63	3.49	2.01
Rose Spring	.27	.08	.33	.37	.48	2.10	1.00
Nawthis Side-notched	.51	.50	.14	.32	.20	n/a	1.00
Bull Creek	.63	.11	n/a	n/a	n/a	n/a	n/a
Desert Side-notched	.75	.51	.27	.22	.32	2.40	1.07
Small Anasazi corner-notched	.40	.07	.41	.73	.47	2.60	1.50
Small Anasazi side-notched	.65	.45	.21	.40	.41	1.20	1.00
Large Anasazi corner-notched	1.13	.29	.78	.99	.51	n/a	3.20
Indeterminate medium, stemmed	.67	.00	.90	.38	1.17	2.73	1.93
Indeterminate stemmed	.75	.34	.45	.42	.63	2.50	2.28
Indeterminate small, triangular	.10	.00	.14	.40	.63	2.00	1.30
Indeterminate leaf-shaped	.30	.00	n/a	n/a	n/a	3.00	n/a
Total							

NOTE: n/a = no data available because no specimens were complete in this measurement.

[a] Total number of specimens used to compute the average distance and angle measurements.

Table 26. Continued.

Point Type	Measurements A1	A2	A3	A4	A5	A6	Total[a]
Lake Mohave	-.20	.56	-1.83	.79	1.28	.24	1
Pinto Series	-.51	.74	-1.30	.22	.99	-.07	12
Sinbad Side-notched	.00	.79	-1.38	1.11	1.55	1.29	3
Humboldt Concave Base	-.20	.79	n/a	n/a	n/a	n/a	2
Northern Side-notched	-.20	1.57	-.59	.32	1.57	1.30	1
Rocker Side-notched	.61	1.81	-1.33	.59	1.25	.51	1
Hawken Side-notched	.00	1.45	-.84	.88	1.54	1.58	4
Sudden Side-notched	-.04	1.41	-.78	.71	1.92	1.87	3
Mount Albion Corner-notched	.14	.77	-1.73	.46	1.17	-.10	1
Oxbow	-.30	.94	-.76	1.05	1.98	2.26	2
McKean Lanceolate	.14	.93	-1.43	1.19	1.49	1.25	1
San Rafael Side-notched	-.40	1.50	-.67	.79	1.76	1.84	5
Gypsum	.29	.85	-1.90	.24	.74	-.93	16
San Rafael Stemmed	.02	.97	-1.55	.03	1.25	-.25	5
Elko Eared	-.45	.76	-1.06	.30	1.33	.58	9
Elko Corner- and Side-notched	.03	1.05	-1.13	.28	1.27	.42	59
Rose Spring	.08	1.17	-1.07	.32	1.15	.40	5
Nawthis Side-notched	-.20	1.57	-3.93	1.90	1.57	-.46	1
Bull Creek	-.33	.46	n/a	n/a	n/a	n/a	2
Desert Side-notched	-.37	1.70	-.52	.89	1.91	2.28	4
Small Anasazi corner-notched	.00	.83	-1.31	.04	1.02	-.26	3
Small Anasazi side-notched	.00	1.57	-.16	1.57	1.81	3.38	2
Large Anasazi corner-notched	.18	1.18	-.84	-.26	.56	-.54	2
Indeterminate medium, stemmed	.06	.81	-1.57	.65	1.31	.40	4
Indeterminate stemmed	-.01	.79	-.98	.68	1.09	.79	7
Indeterminate small, triangular	.00	.39	-2.35	.10	.32	-1.84	3
Indeterminate leaf-shaped	.00	n/a	n/a	n/a	n/a	n/a	1
Total							159

are found in Early Archaic contexts on the Northwestern Plains where they are called Bitterroot (Swanson et al. 1964), Mummy Cave (McCracken et al. 1978) or Pahaska Side-notched (Frison 1978) points.

Rocker Side-notched

One orange chert Rocker Side-notched point (cf. Holmer 1978) was discovered during the survey. It is characterized by moderately high, relatively shallow side notches and a convex, almost semicircular base (Figure 25a). Rocker Side-notched points are thought to date

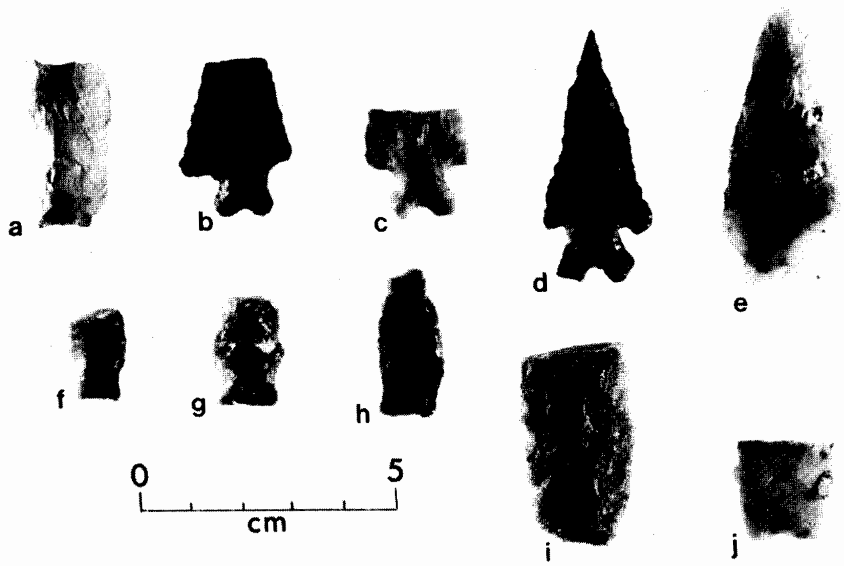

Figure 24. Selected Early Archaic projectile points. a, Lake Mohave; b-e, Pinto Series; f-h, Sinbad Side-notched; i-j, Humboldt Concave Base.

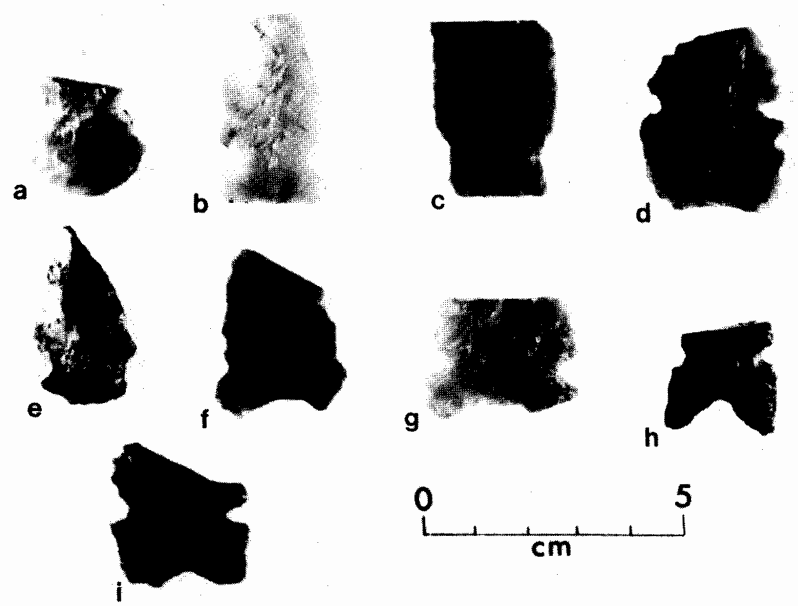

Figure 25. Selected Middle Archaic projectile points. a, Rocker Side-notched; b-c, Hawken Side-notched; d, Sudden Side-notched; e, Mount Albion Corner-notched; f-g, Oxbow; h-i, San Rafael Side-notched.

between 6800 and 5300 B.P. based on evidence from Danger and Cowboy caves (Jennings 1957, 1980) and Sudden Shelter (Jennings et al. 1980). Christensen et al. (1983:51) recently noted a similarity in the morphology of Rocker Side-notched and Basketmaker III points and imply that Rocker points may actually represent Basketmaker III in southwestern Utah. Because there are only gross similarities between the specimen we recovered and the Basketmaker III points they cite (Hayes and Lancaster 1975:145; Rohn 1977:218), we hold to the statistical classification of this point as a Rocker Side-notched. Further analyses will be necessary to test the hypothesis that Rocker Side-notched points date to the Basketmaker III period in southwestern Utah.

Hawken Side-notched

This category includes four fragmentary dart points characterized by lanceolate blades, low, shallow side-notches and straight bases (Figure 25b-c). Hawken Side-notched was originally defined in southwestern Wyoming (Frison et al. 1976) where it is relatively common. It is less frequent on the northern Colorado Plateau, but has been recovered from several surveyed and excavated sites in central and southern Utah (Hauck 1979b; Jennings et al. 1980; Simms 1979). Hawken Side-notched points date between 6500 and 4600 B.P. at Sudden Shelter. Of the four specimens discovered during the survey, two are from Circle Cliffs and two are from the San Rafael Swell. Two each are made from white chert and red-yellow chert.

Sudden Side-notched

Three fragmentary Sudden Side-notched points (cf. Holmer 1978) were observed during the project, two in Circle Cliffs and one in the San Rafael Swell (Table 24). They are characterized by large, triangular blades with straight to slightly convex edges, high horizontal side notches and straight to slightly concave bases (Figure 25d). Material types include gray and white chalcedony and purple chert. Sudden Side-notched points have been identified at a number of sites in central and southern Utah (Hauck 1979a, 1979b; Hunt 1953; Jennings et al. 1980; Jennings and Sammons-Lohse 1981; Kearns 1982; Simms 1979; Tipps 1983) and are thought to date between 6400 and 4700 B.P. (Holmer 1978).

Mount Albion Corner-notched

A whole point identified as a Mount Albion Corner-notched (cf. Benedict and Olson 1978) was discovered on site 42GA2536 in Circle Cliffs (Figure 25e). It is made from mottled red chert and is characterized by a medium-sized triangular blade, shallow side notches and a wide, convex base. This poorly understood type was defined in the Rocky Mountains of Colorado where it dates between 5800 and 4700 B.P. (Benedict and Olson 1978).

Oxbow

Oxbow points, first identified at the Oxbow Dam Site (Nero and McCorquodale 1958) in south central Saskatchewan, are a morphologically distinctive type commonly found on the Northern Plains. They are now thought to occur between 5000 and 2800 B.P. on the Northern Plains and may be earlier in the Rocky Mountain region (Spurling and Ball 1981). Two Oxbow points, one made of gray chert and the other made from red quartzite, were found on two different sites in the San Rafael Swell (Figure 25f-g). Like the type site specimens, they have large triangular blades with straight margins, shallow side notches and wide, markedly concave bases. Oxbow points have been recovered from Cowboy Cave (Jennings 1980:Figure 17r) and several surveyed sites on the northern Colorado Plateau (Kearns 1982:Figure 40:42GA2207#1), but they have been classified as Northern Side-notched or Elko Eared points.

McKean Lanceolate

A single McKean Lanceolate point (cf. Mulloy 1954) was recovered during the project—from site 42GA2530 in Circle Cliffs. This fragmentary point is made from gray chert and has a lanceolate blade with excurvate margins and a straight base. Like Hawken Side-notched points, McKean Lanceolate points are common in the Plains (Reeves 1983), infrequent on the northern Colorado Plateau (Holmer 1978) and apparently absent in the Great Basin (Green 1975; Holmer 1978). McKean Lanceolate points date to between 4800 and 3700 B.P. at Sudden Shelter (Jennings et al. 1980).

San Rafael Side-notched

Five points identifiable as San Rafael Side-notched (cf. Holmer 1978) were discovered during the project: one in Circle Cliffs, three in the San Rafael Swell and one in White Canyon (Figure 25h-i). All of these points have triangular blades, high, shallow side notches and deeply notched or concave bases. Material types include red, black and gray-black chert and pink chalcedony.

The San Rafael Side-notched type was defined at Sudden Shelter where it dates to the

Middle Archaic period, 4600 and 3700 B.P. (Jennings et al. 1980). It occurs in low frequencies in southern Utah (Hauck 1979b), northwestern Arizona (Holmer 1977) and western Colorado (Wormington and Lister 1956). It is similar to the Mallory point found in southwestern Wyoming (Sharrock 1966) and throughout the Northwestern Plains (Frison 1978).

Gypsum

Sixteen Gypsum points (cf. Harrington 1933) were recovered during the project: 5 in Circle Cliffs and 11 in the San Rafael Swell (Figure 26a-c). They have medium to large triangular blades with excurvate margins, short contracting stems and narrow convex bases. Gypsum points generally date between 4600 and 1500 B.P. on the northern Colorado Plateau but occasionally occur on Fremont sites (Holmer 1978). They are among the most common point types at Cowboy Cave (Jennings 1980) and Sudden Shelter (Jennings et al. 1980) and in survey collections from southern Utah (Hauck 1979b; Kearns 1982).

San Rafael Stemmed

San Rafael Stemmed, one of the point types tentatively defined as a result of the discriminant analysis, is characterized by a large slender, triangular blade with straight edges. It has wide corner notches that cause pronounced shoulders or tangs and a relatively long and wide, slightly expanding stem. The base ranges from slightly concave to slightly convex and is markedly square. Overall, it is relatively thin and biconvex in cross section (Figure 26d-g). Average distance and angle measurements differentiating this type are provided in Table 26.

San Rafael Stemmed points are easily distinguished from Gypsum points, the only other named stemmed dart points on the northern Colorado Plateau. The San Rafael Stemmed points have longer and wider stems than Gypsum points and slightly concave to convex, squared bases rather than markedly convex bases. They also have slightly expanding rather than contracting stems, and, unlike Gypsum points whose stems are formed by the notching process, they have elongated stems that were deliberately flaked. San Rafael Stemmed points are also distinctive from the stemmed San Jose points (cf. Irwin-Williams 1973; Irwin-Williams and Tompkins 1968) found on the southern Colorado Plateau. Unlike the San Rafael Stemmed, San Jose points are serrated and have

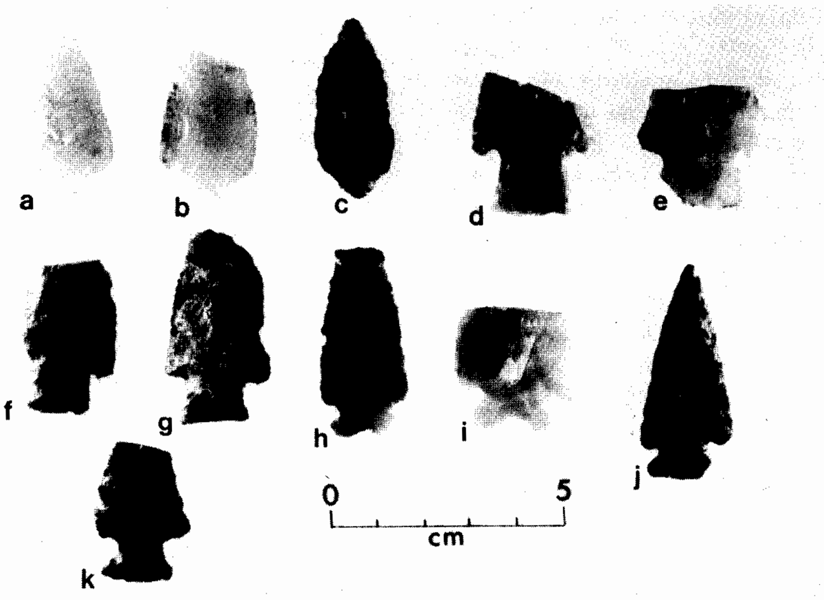

Figure 26. Selected Late Archaic and Elko projectile points. a-c, Gypsum; d-g, San Rafael Stemmed; h-k, Elko Series.

markedly concave bases and poorly defined shoulders.

Five specimens identifiable as San Rafael Stemmed were discovered during the project: two in Circle Cliffs and three in the San Rafael Swell. Material types include red and purple chert, and white and gray chalcedony. San Rafael Stemmed points occur on the surface with Pinto, Elko and Gypsum points and apparently date to the Archaic period. Additional investigations and the recovery of similar points from well-dated, stratified deposits will be necessary to refine and confirm the temporal range suggested by this limited surface evidence.

Elko Series

Elko series (cf. Heizer and Baumhoff 1961; Heizer et al. 1968), the most common point type discovered during the project, comprises 23% of the point assemblage (Figure 26h-k). The Elko points are characterized by triangular blades with straight margins. The corner- and side-notched varieties have slightly concave to convex bases. The eared points are corner notched and have markedly concave bases. Three broken Elko points have been reworked into scrapers.

Seventy Elko points were recorded during the project: 20 in Circle Cliffs, 49 in the San Rafael Swell and 1 in White Canyon (Table 24). Nine of these are eared: one from Circle Cliffs and eight from the San Rafael Swell. Gray-white chalcedony is the most common material type, followed by red chert, gray chert, multicolored chalcedony, quartzite and white chert. Most of the red chert points are from Circle Cliffs; gray-white chalcedony predominates in the San Rafael Swell collection. Elko points occur in Archaic (Jennings 1980; Jennings et al. 1980), Anasazi (Kidder and Guernsey 1919), Fremont (Jennings and Sammons-Lohse 1981) and possibly Paiute contexts (Holmer 1978:62) and are one of the least temporally diagnostic dart points found on the northern Colorado Plateau. Some believe that the Elko Eared variety is temporally diagnostic and that it dates between 7500 and 3700 B.P. on the northern Colorado Plateau (Holmer 1978).

Rose Spring

Three Rose Spring points (cf. Lanning 1963), two of red chert and one of white chalcedony, were discovered on three sites in Circle Cliffs (Figure 27a-b). They have small, slender, triangular blades with lightly serrated, straight edges. They also have corner and/or basal notches that result in slightly tanged shoulders and parallel-sided to expanding stems. Rose Spring points are thought to mark the transition to the bow and arrow. They date between roughly A.D. 300 and 925 on the northern Colorado Plateau (Holmer and Weder 1980) but continue until roughly A.D. 1500 in the Great Basin (Touhy 1979). They occur in very Late Archaic contexts throughout the Desert West and are common on Fremont sites near the San Rafael Swell (Aikens 1967; Holmer and Weder 1980; Jennings and Sammons-Lohse 1981; Taylor 1957) and Anasazi sites in southeastern Utah (Long 1966; Sharrock 1964).

Nawthis Side-notched

A red chert Nawthis Side-notched point (cf. Holmer and Weder 1980) was recovered from site 42EM1749 in the San Rafael Swell (Figure 27c). It has a small, triangular blade, high side notches and a straight base. Nawthis side-notched points occur throughout the central and portions of southern Utah and date between A.D. 950 and 1250 (Holmer and Weder 1980).

Bull Creek

Two chalcedony Bull Creek points (cf. Weder and Sammons-Lohse 1981) were recovered in the White Canyon study tract. The points are small, triangular and unnotched (Figure 27d). They have straight blade margins and concave bases that emphasize basal corners. Bull Creek points are common in Pueblo sites in southern Utah (Hauck 1979b; Lipe 1960; Sharrock and Keane 1962) where they date between A.D. 1100 and 1250 (Holmer and Weder 1980).

Desert Side-notched

Two complete and two fragmentary Desert Side-notched points (cf. Baumhoff and Byrne 1959) were recovered from two sites and one isolated find in the San Rafael Swell and one

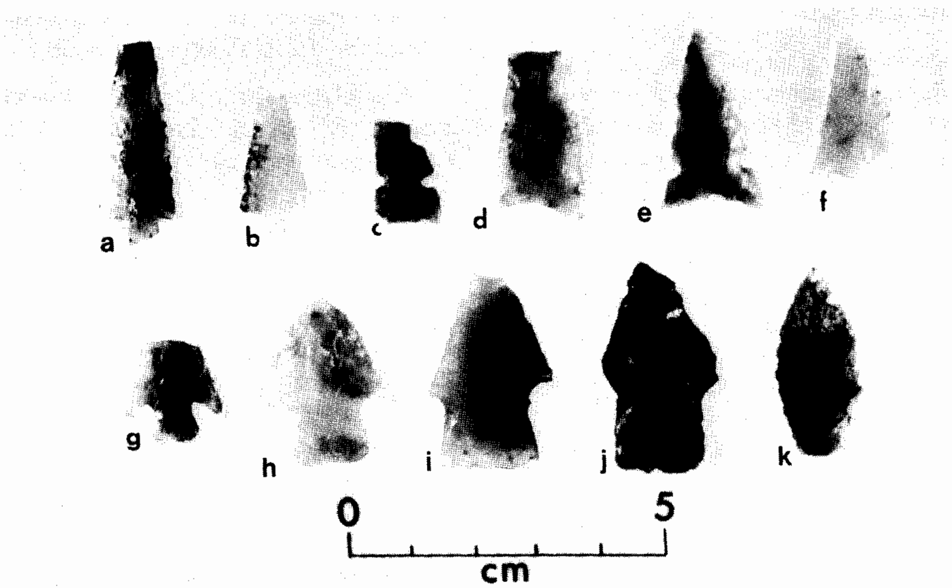

Figure 27. Selected arrow and indeterminate projectile points. a-b, Rose Spring; c, Nawthis Side-notched; d, Bull Creek; e, Desert Side-notched; f-g, small Anasazi Corner-notched; h-j, indeterminate medium, stemmed; k, indeterminate leaf-shaped.

site in Circle Cliffs (Figure 27e). They are small, triangular, side-notched points with straight blade margins and concave bases. Material types include white and gray chalcedony. Desert Side-notched points are found after A.D. 300 on the northern Colorado Plateau (Holmer and Weder 1980).

Small Anasazi corner-notched

These corner-notched arrow points are characterized by small, lightly serrated, triangular blades (Figure 27f-g). The corner notches create distinct, pointed tangs and expanding stems. Although some would consider these points within the Rose Spring range, they are wider in relation to their length and have more pronounced expanding stems than those we have designated as Rose Spring. The two specimens were found in the White Canyon study tract and are made from white and tan chalcedony. Similar points appear in Basketmaker III and Pueblo I contexts in the Four Corners region (Brew 1946; Hayes and Lancaster 1975).

Small Anasazi side-notched

Two tiny arrow points resembling Bear River Side-notched points (cf. Holmer and Weder 1980) were found on Pueblo sites in the White Canyon study tract. They have small triangular blades, large horizontal side notches and exaggerated bases that are wider than the blade. They are made from brown chert and brown chalcedony. Similar points are found in Pueblo II and III sites throughout the Four Corners area (Brew 1946; Kidder and Guernsey 1919; Rohn 1977).

Large Anasazi corner-notched

This category is comprised of two large, brown chert, corner-notched dart points that may have been used as hafted knives. Both were found in White Canyon.

Indeterminate medium, stemmed

The three medium-sized, stemmed dart points are characterized by triangular blades, wide stems of moderate length and straight to slightly convex bases (Figure 27h-j). They have wide corner notches causing pronounced sloping shoulders. Two are made from gray chalcedony; the other is made from grayish brown chert. All three points are from the San Rafael Swell.

Indeterminate stemmed

Six indeterminate stemmed dart points were collected during the project, two in Circle Cliffs, three in the San Rafael Swell and one in White Canyon. They are characterized by short but wide triangular blades, wide stems and concave to convex blade margins. Material types include gray and white chalcedony, as well as red and multicolored chert.

Indeterminate small, triangular

Three small, indeterminate triangular arrow points were found, one in each study tract. They have small triangular blades, straight, slightly serrated blade margins and short, narrow stems. Two are made from chalcedony. The other appears to be made from siltstone.

Indeterminate leaf-shaped

This category contains a single, lenticular-shaped red-gray chert point with a straight, narrow base (Figure 27k). It has slightly serrated margins and appears to have been made from a flake. Similar points were recovered from Early Archaic strata at O'Malley Shelter (Fowler et al. 1973), Danger Cave (Jennings 1957) and Sudden Shelter (Jennings et al. 1980).

Indeterminate

This category contains a wide variety of triangular and lanceolate dart points. Bases range from concave to convex to indented. Several are stemmed while others have corner and/or side notches. None conform to a named morphological type.

Summary and Discussion

Analysis of the projectile points resulted in the identification of 17 named, 8 unnamed and 2 new point types (San Rafael Stemmed and Sinbad Side-notched). Most of the types have been previously identified in or near the study tracts where they were found during the present work. The exceptions are Oxbow and Mount Albion points which have not been previously identified on the northern Colorado Plateau. The implications of these points and the more commonly occurring Plains types such as McKean Lanceolate and Hawken Side-notched are interesting but will require further investigations before substantive conclusions can be made.

Most of the chronologically sensitive points date to the Archaic time period, with only a small number of points unequivocally demonstrating Anasazi and Fremont occupation. The paucity of "late" projectile points in the Circle Cliffs study tract contrasts with collections from excavated sites such as Coombs Village where most of the points are relatively late arrow points such as Bull Creek and Parowan Basal-notched. This difference may be more apparent rather than real, however, because excavation projects have generally focused on late sites (Fowler 1963; Fowler and Aikens 1963; Lister and Lister 1961) to the exclusion of earlier sites of more limited activity. The predominance of Archaic point types accords well with previous survey work near Circle Cliffs (Hauck 1979a, 1979b; Kearns 1982). The same is true for the San Rafael Swell (Berge 1974; Hauck 1979a; Thomas et al. 1981).

It is noteworthy that the frequency of material types in the Circle Cliffs and San Rafael Swell point collections roughly parallels that observed in the debitage analysis presented in the succeeding section. Red chert and multicolored chalcedony dominate the collection from Circle Cliffs. Gray-white chalcedony is most common among the San Rafael points.

In White Canyon, a low-quality blue-gray chert is the most common material present in the debitage. Formal tools, on the other hand, are made from a variety of high-quality cherts and chalcedonies, materials which occur in low frequencies in the debitage. Flakes from these high-quality materials that do occur are generally indicative of later reduction stages. These finds imply that the high-quality materials were obtained from nonlocal sources—possibly the gravel terraces along the Colorado River—and that they were reduced into blanks or preforms before being brought to White Canyon for use and further reduction. Evidently, the blue-gray chert was available locally, and was used to make expedient tools that did not require a high-quality material.

Other Chipped Stone Tools, Cores and Debitage

by Craig S. Smith

This section describes the chipped stone tools, other than projectile points, and debitage from a technological and morphological perspective. In this approach, stone tool manufacture is viewed as a series of stages ranging from the selection of raw materials and removal of the first few flakes to the final shaping of the desired tool (Flenniken 1981; Tipps 1983). Following descriptions of the technology and morphology of the collection, discussions and comparisons will be made of the chipped stone tools and debitage found in the Circle Cliffs and San Rafael Swell study tracts.

Besides the projectile points, a total of 702 chipped stone tools was noted during the survey, including 590 bifaces, 41 unifaces, 9 drills and 62 cores (Table 27). Some 50,000 pieces of debitage were also observed and recorded. All of these appear to have been produced using a bifacial reduction technology that included direct freehand percussion and pressure flaking.

Bifaces

Artifacts exhibiting flaking on both faces and around the entire perimeter were classified as bifaces. Some projectile point tips and midsections are probably also included in this category. A total of 590 bifaces was recorded on sites or as isolated finds during the survey. Table 27 shows the total number of bifaces by study tract. Bifaces, the most common chipped stone tool, are found on at least 70% of the lithic scatter sites in the Circle Cliffs and San Rafael Swell study tracts (Table 28).

From a technological perspective, as illustrated by Holmes (1919:Figure 49), biface production can be viewed as a series of sequential steps beginning with the removal of the first flakes to the completion of the tool. Bifaces can be grouped as either blanks, preforms or end products, depending on their stage within the bifacial reduction continuum (Crabtree 1972; cf. Tipps 1983). Blanks, the first stage, are thick, angular bifaces that are irregular in outline and often exhibit cortex. They are usually suitable for making a number of tool types. Preforms represent the next stage and contain less mass and cortex than blanks. End products or finished tools are generally thin in cross section, regular in outline and exhibit pressure flaking. A biface could be used as a tool at any stage in the process or discarded due to defects in the material or breakage during manufacture or use.

The biface assemblage recorded during the project includes the full range of blanks, preforms and end products. Most of these bifaces appear to be rejects that were discarded during manufacture. Although fragmentary blanks and preforms dominate the collection, several finely worked bifaces were collected

Table 27. Frequency of chipped stone tools from sites and isolated finds by study tract.

Chipped Stone Tool Type	Circle Cliffs	San Rafael Swell	White Canyon	Total
Projectile point	63	209	31	303
Biface	231	324	35	590
Uniface	14	23	4	41
Drill	2	7	0	9
Core	17	41	4	62
Total	327	604	74	1005

Table 28. Frequency and percent of sites containing chipped stone tools by study tract.

Chipped Stone Tool Type	Circle Cliffs		San Rafael Swell		White Canyon
	n	%	*n*	%	*n*
Projectile point	25	47	53	66	11
Biface	39	73	56	70	9
Uniface	6	11	15	19	4
Drill	1	2	5	6	0
Core	5	9	16	20	2

from the Circle Cliffs and San Rafael Swell study tracts. The Circle Cliffs specimens are predominantly triangular in outline and have straight margins and distinctive square to slightly rounded bases (Figure 28h-j). They are biconvex and thin in cross section and are approximately 7 cm long and 3 to 4 cm wide. The length is approximate because all are missing the tip. These bifaces probably represent finished tools or end products.

In addition to the specimens noted above, a number of fairly thin, asymmetrical bifaces were found in the San Rafael Swell (Figure 28a-c). These bifaces have one relatively straight margin and one convex margin with both ends generally forming a point. Occasionally, one end is squared off forming a base, possibly for hafting (Figure 28b). These bifaces range from about 7 to 14 cm long and are about 3 to 4 cm wide.

One very large, thin, ovoid biface was collected from a site located outside the survey quadrats in the San Rafael Swell (Figure 28d). This unusual end product is 14 cm long and 8 cm wide. It is made of a dark gray chert which appears to have been heat treated.

Unifaces

Flaked stone artifacts exhibiting unifacial retouch were classified as unifaces. This category also contains tools traditionally called "scrapers" or "end scrapers." During the project, 41 unifaces were recorded on sites or as isolated finds. Table 27 shows the total number of unifaces by study tract; Table 28 indicates the number and percentage of sites containing unifaces. A minor part of the total tool assemblage, the unifaces occur on less than 20% of the sites.

These tools, produced by chipping the dorsal surface of large flakes, range from about 4 to 8 cm long. Many display flake scars only along the distal portion of the edge, while others are chipped around the entire perimeter. Several unifaces exhibit fine retouch on one or more edges.

Drills

Nine bifacially chipped stone tools characterized by a long, narrow bit were classified as drills (Table 27). The bits of these finely chipped artifacts have thick triangular (Figure 28g) to thin biconvex (Figure 28f) cross sections. The only complete drill, found in the San Rafael Swell study tract, is about 5 cm long. Several of the drills have bases measuring 1.0 to 1.5 cm wide. One drill has a side-notched base and appears to be a reworked Northern Side-notched point (Figure 28f).

Two drill fragments were found at one site in the Circle Cliffs study tract; the remaining seven specimens occurred on five sites in the San Rafael Swell (Table 28). No drills were noted in the White Canyon study tract.

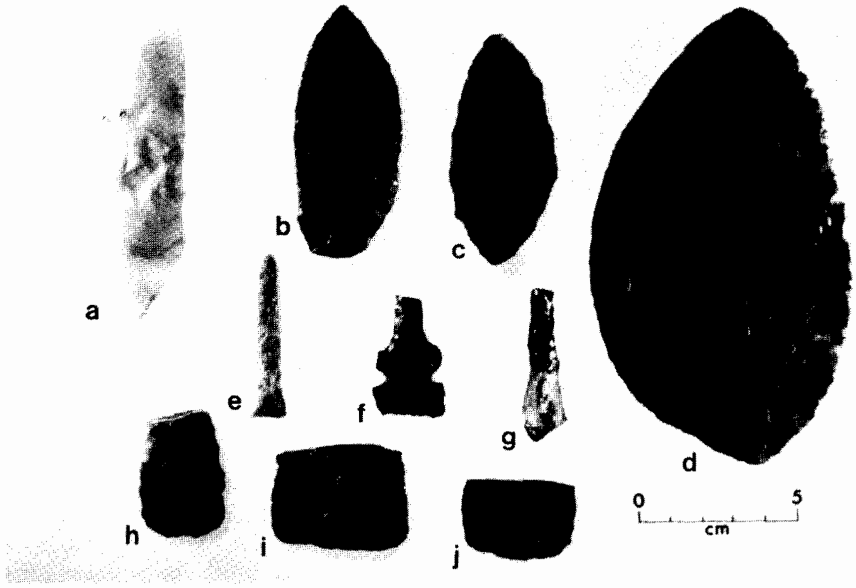

Figure 28. Selected bifaces and drills. a-d, h-j, bifaces; e-g, drills.

Cores

Artifacts included in this category are actually the remnants of the flaking process and are not necessarily tools. They usually exhibit a facet or striking platform from which flakes were removed. A total of 62 cores was recorded on 23 sites during the survey, with the majority occurring in the San Rafael Swell (Tables 27-28).

Debitage

Debitage, including shatter, chunks and flakes, is the material detached from a piece of stone during the various stages of tool manufacture (Chapman 1977). The debitage from each manufacturing stage displays distinguishing attributes that allow individual flakes to be classified into the various stages in the reduction sequence. Flakes from any stage in the reduction sequence could have been used as tools.

During the survey, the debitage at each site was separated into four groups. These groups—decortication, primary thinning, secondary thinning and final shaping—represent the various steps in the manufacture of stone tools by bifacial reduction (Crabtree 1972). The decortication category includes flakes reflecting the first stage of core reduction and includes flakes with cortex on the dorsal surface. The early stages of biface manufacture produce thick angular flakes, often with cortex, which are classified as primary thinning flakes.

Flakes representing bifacial thinning are included in the secondary thinning category and are usually fairly thin in cross section and display some flake scars on the dorsal surface. The final shaping group consists of flakes reflecting the last stages of tool manufacture. These flakes may be the result of pressure flaking whereas the debitage from the earlier steps are probably produced by direct freehand percussion. Microflakes, which may be shatter produced at any reduction stage, also were noted on many sites.

Secondary thinning flakes are the most common type of flake on the majority of the sites in all three study tracts (Table 29). They predominate on over 60% of the sites in both the Circle Cliffs and San Rafael Swell study tracts and most of the sites in White Canyon. The predominance of secondary thinning flakes indicates that cores or cobbles were reduced into rough blanks elsewhere, probably at the quarry areas, and then brought to the sites for further reduction. The few sites containing mostly decortication flakes occur on the cobble/gravel terraces along the San Rafael River.

Following the IMACS User's Guide, the number of flakes observed on each site was

Table 29. Frequency and percent of sites by most common flaking stage and study tract.

Flaking Stage	Circle Cliffs *n*	Circle Cliffs %	San Rafael Swell *n*	San Rafael Swell %	White Canyon *n*
Decortication	1	2	4	5	0
Primary thinning	7	13	13	16	2
Secondary thinning	34	64	49	61	14
Final shaping	5	10	6	8	2
More than one stage	6	11	8	10	2
Total	53	100	80	100	20

recorded into the following categories: 1-9, 10-25, 26-100, 101-500 and over 500 flakes. Table 30 shows the number of sites for each category by study tract. In both the San Rafael Swell and Circle Cliffs study tracts, sites containing between 26 to 100 flakes are the most common; sites with over 500 flakes are more common in Circle Cliffs, however, than in the San Rafael Swell.

The principal materials on most sites in the Circle Cliffs study tract are a multicolored, red and yellow chert, probably from the Chinle Formation, as well as a clear chalcedony. Occurring in lesser quantities are cherts of various other colors, chalcedonies, quartzites, mudstones, petrified woods and basalts. The most common material types appear to be from the same or similar sources without noticeable changes across the study tract; the locations of the actual quarries are unknown. One unique site in Circle Cliffs contains mostly black petrified wood that probably occurs naturally in the Chinle Formation on or near the site. Several obsidian flakes and one obsidian biface were also recovered from three sites in Circle Cliffs.

The material types in the San Rafael Swell study tract are more varied than those in Circle Cliffs with the most common types being white chalcedony and gray chert. White chalcedony appears to be the predominant material on sites in the southern portion of the study tract while in the northern section, cherts of various colors are also common. The sources for most of the materials were not located during the survey. The cobble/gravel terraces along the San Rafael River contain material types that are not generally found on sites away from the river.

The most common material type in the White Canyon study tract is blue-gray chert. This appears to be the main material at sites located on the flats above Lost Canyon as well as those on the high mesas south of White Canyon. Among the various other materials are cherts of several colors, white and gray chalcedonies, quartzite, and petrified wood. Several unflaked nodules of petrified wood were found at the sites on the flats above Lost Canyon. These appear to have been carried to the sites in anticipation of reduction.

Discussion

Of the 153 sites recorded within the survey quadrats, 120 have at least one chipped stone tool (Table 31). Over half contain four or fewer tools while three sites have more than 50 tools (Figure 29). The distribution is positively skewed with most sites containing only a few artifacts.

To explore the relationship between the number of chipped stone tools and site size in the Circle Cliffs and San Rafael Swell study tracts, a Kruskal and Goodman coefficient of ordinal association was computed (Freeman 1965) using the data shown in Table 32. A gamma

Table 30. Frequency and percent of sites by number of flakes and study tract.

Flake Count Category	Circle Cliffs *n*	Circle Cliffs %	San Rafael Swell *n*	San Rafael Swell %	White Canyon *n*
1 - 9 flakes	0	0	5	6	1
10 - 25 flakes	8	15	13	16	6
26 - 100 flakes	18	34	32	40	5
101 - 500 flakes	10	19	16	20	5
> 500 flakes	17	32	14	18	3
Total	53	100	80	100	20

Table 31. Frequency of chipped stone tools by study tract.

Study Tract	Frequency	Sites with Tools *n*	Sites with Tools %	Median Number of Tools per Site
Circle Cliffs	327	42	79	4
San Rafael Swell	604	66	83	4
White Canyon	74	12	n/a	n/a
Total	1005	120	78	n/a

correlation coefficient of .60 was obtained. A coefficient of .62 was computed for the relationship between the number of tools and the frequency of flakes on a site (Table 33). Because the gamma coefficient ranges between 0 and 1, these coefficients demonstrate a moderate positive correlation between the number of tools and site size and the frequency of tools and flakes. That is, as tool frequency increases, so do flake frequency and site size. Similar coefficients were obtained when the data from the Circle Cliffs and San Rafael Swell study tracts were computed separately.

The chipped stone assemblage recorded in the Circle Cliffs and San Rafael Swell study tracts is similar. The White Canyon study tract, with only 20 recorded sites, has too few chipped stone artifacts for meaningful comparisons. Approximately 80% of the sites in both Circle Cliffs and the San Rafael Swell contain at least one chipped stone tool (Table 31). The median number of tools on sites with tools is also about the same (Table 31) as is the percentage of sites with bifaces (Table 28); however, the Circle Cliffs area has a lower percentage of sites with projectile points. This may only be the result of greater "arrowhead" collecting activities in this easily accessible area. Another similarity is that the debitage on about 60% of the sites in both areas is mainly secondary thinning flakes (Table 29).

In summary, the chipped stone assemblages on most of the sites in Circle Cliffs and the San Rafael Swell appears to represent the production of preforms or end products from blanks brought to the site. The lack of debris from

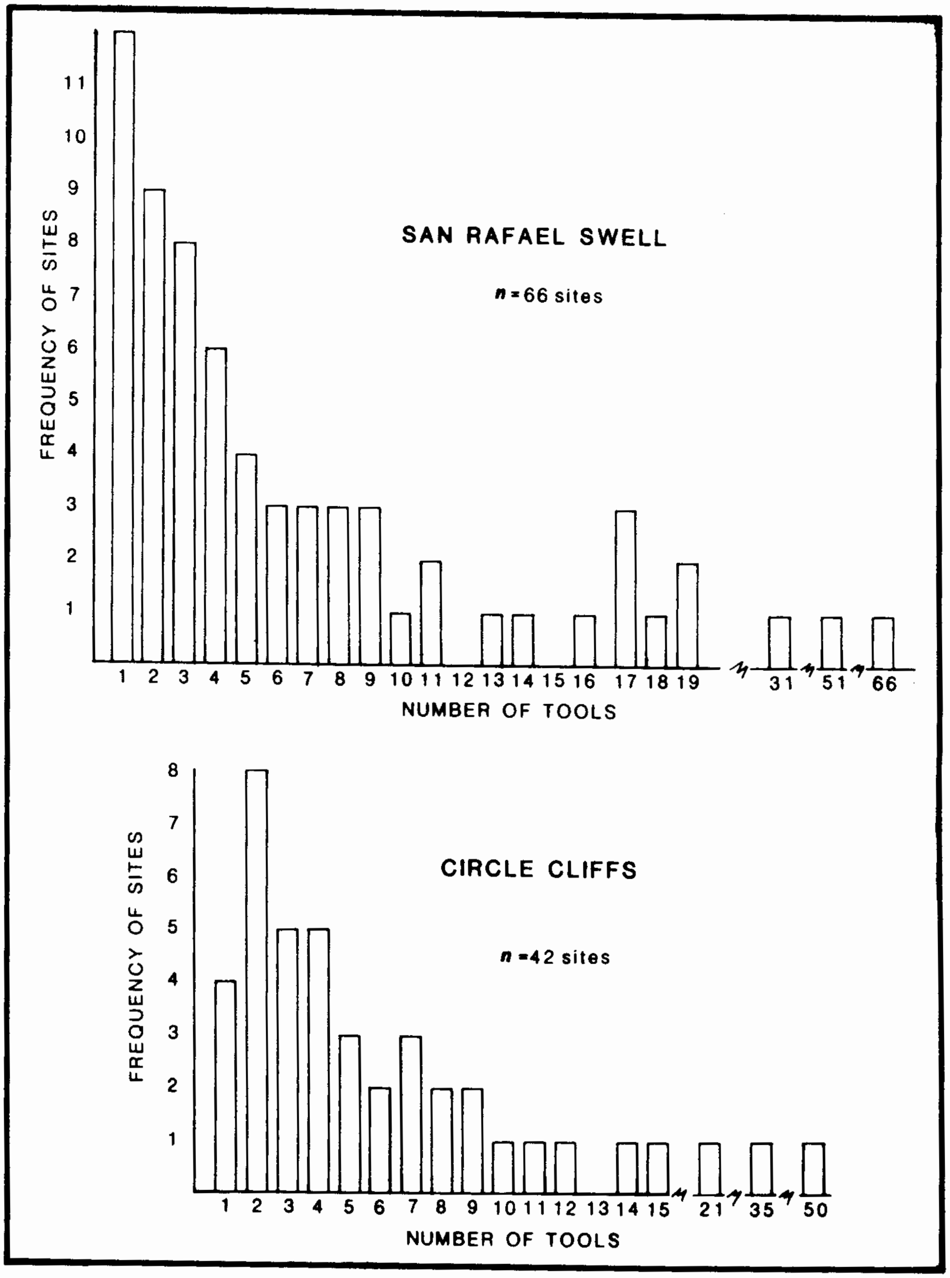

Figure 29. Bar graph of the frequency of sites by number of tools for the Circle Cliffs and San Rafael Swell study tracts.

initial stages of reduction, including cores and cobbles, also suggests an emphasis on bifacial thinning activities.

Ground Stone

The ground stone assemblage recorded during the project consists of 78 whole and fragmentary grinding implements: 15 in Circle Cliffs, 43 in the San Rafael Swell and 20 in

Table 32. Frequency of sites in Circle Cliffs and the San Rafael Swell by number of tools and site size.

Number of Tools	Site Size (m^2) < 1000	1000-3000	3000-8000	> 8000	Total
Sites without tools	15	5	2	3	25
Sites with < 5 tools	21	19	15	9	57
Sites with 5-9 tools	4	10	9	5	28
Sites with > 9 tools	1	1	6	15	23
Total	41	35	32	25	133

Table 33. Frequency of sites in Circle Cliffs and the San Rafael Swell by number of tools and flakes.

Number of Tools	Flake Count Categories 1-9	10-25	26-100	101-500	>500	Total
Sites without tools	3	10	7	4	1	25
Sites with < 5 tools	2	12	27	8	8	57
Sites with 5-9 tools	0	2	11	7	8	28
Sites with > 9 tools	0	0	2	7	14	23
Total	5	21	50	26	31	133

White Canyon. Seventy-four of these were discovered on sites. Three manos and one metate were recorded as isolated finds. Within the total assemblage, 44% (34) are manos or handstones; 56% (44) are metates. Overall, one-hand cobble manos and portable slab metates are the most common types of grinding implements.

Three types of milling stones were noted during the project—slab, basin and trough (Table 34). Slab, or flat metates, the most common type in the project area, are characterized by wear covering the entire surface. Basin metates, which comprise 19% of the assemblage, are distinguished by an oval grinding depression, indicating circular grinding motion. Trough metates make up only 9% of the collection and are characterized by a subrectangular grinding surface surrounded by a rock lip on three sides. Utah-type metates, common in Fremont contexts (Aikens 1967; Taylor 1957), were not discovered during the project.

Most of the metates are made from locally available sandstone slabs that probably derive from the Wingate Formation. A notable exception is a vasicular basalt trough metate from site 42EM1681 near Tan Seep in the San Rafael Swell. In general, the metates are characterized by a lack of, or only minimal, margin shaping, indicating fairly expedient use. The exceptions are the trough metates which were pecked and ground and a few of the slab metates which are

Table 34. Frequency of milling stones by type and study tract.

Study Tract	Slab Metate	Basin Metate	Trough Metate	Total
Circle Cliffs	4	1	1	6
San Rafael Swell	20	6	3	29
White Canyon	7	1	0	8
Total	31 (72%)	8 (19%)	4 (9%)	43

pecked and spalled. The metates range from minimally worn to well worn, with most being in the former category. The exception again is the trough metates which are generally well worn. The grinding surfaces of most of the metates are pitted from resharpening.

One unusual find was a pecked, lightly ground, flat slab metate propped up by small stones to create an informal mealing bin. Two one-hand manos were found on the same site, site 42EM1698 near Oil Well Draw in the San Rafael Swell.

The mano assemblage consists of 30 one-hand manos and a single two-hand mano. The manos are made from quartzite, sandstone and igneous river cobbles, and thin sandstone slabs. One-hand sandstone cobble manos are the most common type. The predominance of one-hand manos in Circle Cliffs and the San Rafael Swell would be expected given the abundance of Archaic sites in these areas and the generally accepted notion that one-hand manos were used to process wild plant foods rather than maize (Jennings et al. 1980). The predominance of one-hand manos in the White Canyon tract may indicate the importance of wild plant foods in the diet of the Anasazi who lived in this area.

Mano shapes range from subrectangular to oval with the latter being the most common. Some are shaped by pecking and grinding, but more frequently, no shaping is evident. Unifacial and bifacial manos are present in roughly equal proportions. Cross sections vary from subrectangular, ovate, and wedge-shaped to circular. The amount of wear present on the manos ranges from slight to heavy with most exhibiting slight to moderate wear. Pecking is present on most of the well-worn manos, indicating resharpening and repeated use. A number of the manos are also battered on the ends, indicating pounding, crushing or striking activities.

Circle Cliffs and the San Rafael Swell contain a similar percentage of sites with ground stone, 19% and 18%, respectively (Table 35), even though considerably more sites were recorded in the San Rafael Swell. This similarity suggests that plant processing sites had the same relative importance in the seasonal round of both areas. A considerably higher percentage of sites in White Canyon have ground stone (Table 35), probably reflecting the more sedentary nature of the occupation in this area.

The average number of ground stone implements on sites containing ground stone is much higher in the San Rafael Swell than in Circle Cliffs (Table 35). This difference may indicate that plant processing sites were more specialized or more extensively utilized in the Swell.

Table 36 shows the frequency of manos and metates discovered on sites in each of the study tracts. Relative to the number of sites containing ground stone, all three contain a similar percentage of manos or handstones. The San Rafael Swell, relative to the other areas, contains a larger percentage of milling stones. This relative abundance may indicate more frequent reuse of plant processing sites in the San Rafael Swell.

Table 35. Frequency of ground stone and sites containing ground stone, and average number of ground stone artifacts per site with ground stone by study tract.

Study Tract	Ground Stone Frequency	Sites with Ground Stone *n*	Sites with Ground Stone %	Average Number Ground Stone/Site with Ground Stone
Circle Cliffs	14	10	19	1.4
San Rafael Swell	41	14	18	2.9
White Canyon	19	10	50	1.9
Total	74	34	22	2.2

Table 36. Frequency of ground stone from sites by study tract.

Study Tract	Mano/Handstone	Milling Stone/ Metate	Total	Manos:Metates
Circle Cliffs	8	6	14	1:0.9
San Rafael Swell	12	29	41	1:2.8
White Canyon	11	8	19	1:0.8
Total	31	43	74	1:1.4

Pottery

by William A. Lucius

During the course of the project, approximately 880 sherds were observed on 16 sites in the White Canyon tract and on 6 sites and 4 isolated finds (IF's) in the San Rafael Swell. No pottery was found in the Circle Cliffs study tract. Although not required by the contract, 169 of the sherds were collected so they could be analyzed by a professional ceramist to determine the general cultural and temporal affiliations of the associated sites. Although the lack of a structured sampling design for the collection procedure precludes secure assignments for any one site, the general pattern of occupation may be discussed for the two areas.

The assignment of ceramics to a particular cultural group is based on the analysis of temper type as determined by binocular microscope inspection. The available mineral resources that were selected for use in the manufacture of ceramics are known to vary across space, and documentation of their variability allows for the association of particular temper types with those groups responsible for their production (Lucius 1981). The ceramics were analyzed according to procedures outlined in Lucius (1982), and they represent ten ceramic wares or technological traditions indicative of Kayenta and Mesa Verde Anasazi groups (Breternitz et al. 1974; Colton 1955, 1956; Lucius and Wilson 1981) as well as the San Rafael and Parowan Fremont (Madsen 1977). Technological traditions present include Tusayan Gray and White Ware, Tsegi Orange Ware, Mesa Verde Gray, White and Red Ware, Awatovi and Jeddito Yellow Ware, as well as Utah Desert and Fremont Gray Ware. The distribution of pottery by site is presented in a table in Appendix 1.

The affiliation of ceramics with temporally sensitive pottery types further requires the recognition of diagnostic decorative attributes, such as painted designs or surface manipulations. The assignment of a ceramic artifact to a type with a geographical place name allows for a relatively secure determination of its age, whereas grouped types such as Corrugated Body Sherds or Late Pueblo White can only be assigned to broad periods of manufacture and use (from A.D. 900 to A.D. 1300 for these two types). The use of a ware designation (e.g., white ware) indicates that type status cannot be determined. An estimate of the general age of an assemblage is accomplished by inspection of the ceramic types and their associated dates.

The White Canyon survey area, although often included within the Mesa Verde region of the northern Anasazi (Breternitz et al. 1974:Figure 21), reveals a preponderance of ceramics affiliated with the Kayenta Anasazi. Kayenta ceramics are recognized by the presence of quartz sand temper (primarily in the utility or gray wares) or a mixture of quartz sand and crushed sherd (in the white and red wares). The associated ceramic types suggest a time period of occupation between A.D. 1050 and 1200 (Colton 1955, 1956). The companion Mesa Verde ceramics support a late Pueblo II to early Pueblo III temporal assignment.

One site (site 42SA14422) is anomalous in that its associated ceramics suggest a post-Pueblo III date of use. The distinctive Jeddito Black-on-yellow pottery recovered from the site is of indisputable Hopi manufacture, but the recovery of this type in southeastern Utah does not necessarily indicate a Hopi presence in the area (Schaefer 1969). The wide if spotty distribution of Jeddito Yellow pottery across southern Colorado and southern Utah may instead reflect Shoshonean use of Western Pueblo trade ceramics after A.D. 1400 (Lucius 1983). Similarly, it is difficult to confidently assign the sites of the White Canyon area to either the Mesa Verde or Kayenta Anasazi without further sampling and analysis.

Ceramic items recovered from the San Rafael area represent various cultural affiliations, with a strong Fremont presence being indicated. Fremont ceramic types were defined by reference to Madsen (1977) and include Emery Gray (with a distinctive crushed basalt temper), Snake Valley Gray and Snake Valley Corrugated (with a crushed igneous temper composed primarily of quartz, feldspar and biotite mica). A time period extending from A.D. 900 to 1200 would account for the ceramics recovered by the survey activities. Although the survey area is within the San Rafael Fremont region (Madsen 1977:Figure 1), Parowan Fremont ceramics predominate the collection.

The single Kayenta Anasazi corrugated body sherd (from site 42EM1701) found in the San Rafael Swell is not considered to be an unusual occurrence due to the wide distribution of Kayenta Anasazi ceramics in central Utah (Hauck 1979a:316; Hauck et al. 1978:33). The Kayenta and Mesa Verde Anasazi ceramics of SR-13-IF2 and SR-13-IF7 were collected from a historic trash dump (Betsy L. Tipps, personal communication) and may be interpreted as evidence of the collection of attractive artifacts from several, probably nonlocal, sites.

In summary, ceramic analysis of 169 sherds was undertaken to determine the temporal and cultural affiliations of the various sites and isolated finds. Kayenta and Mesa Verde Anasazi pottery diagnostic of the late Pueblo II/early Pueblo III period characterizes the White Canyon area. A Fremont presence between A.D. 900 and 1200 is suggested for the San Rafael Swell survey area.

Perishable Artifacts

The perishable artifacts consist of a complete fire drill and fire-drill hearth, a bone pendant, a possible digging stick and scattered juniper bark and grass chaff in the fill of two rockshelter sites. The fire drill and fire-drill hearth were recovered from site 42EM1722, a rockshelter site in Oil Well Draw in the northern end of the San Rafael Swell. The fire drill consists of a curved wooden shaft 83 cm long and 1 cm in diameter (Figure 30a). One end tapers to a point; the other end, which was used as a fire drill, is burned and slightly conical (Figure 30c).

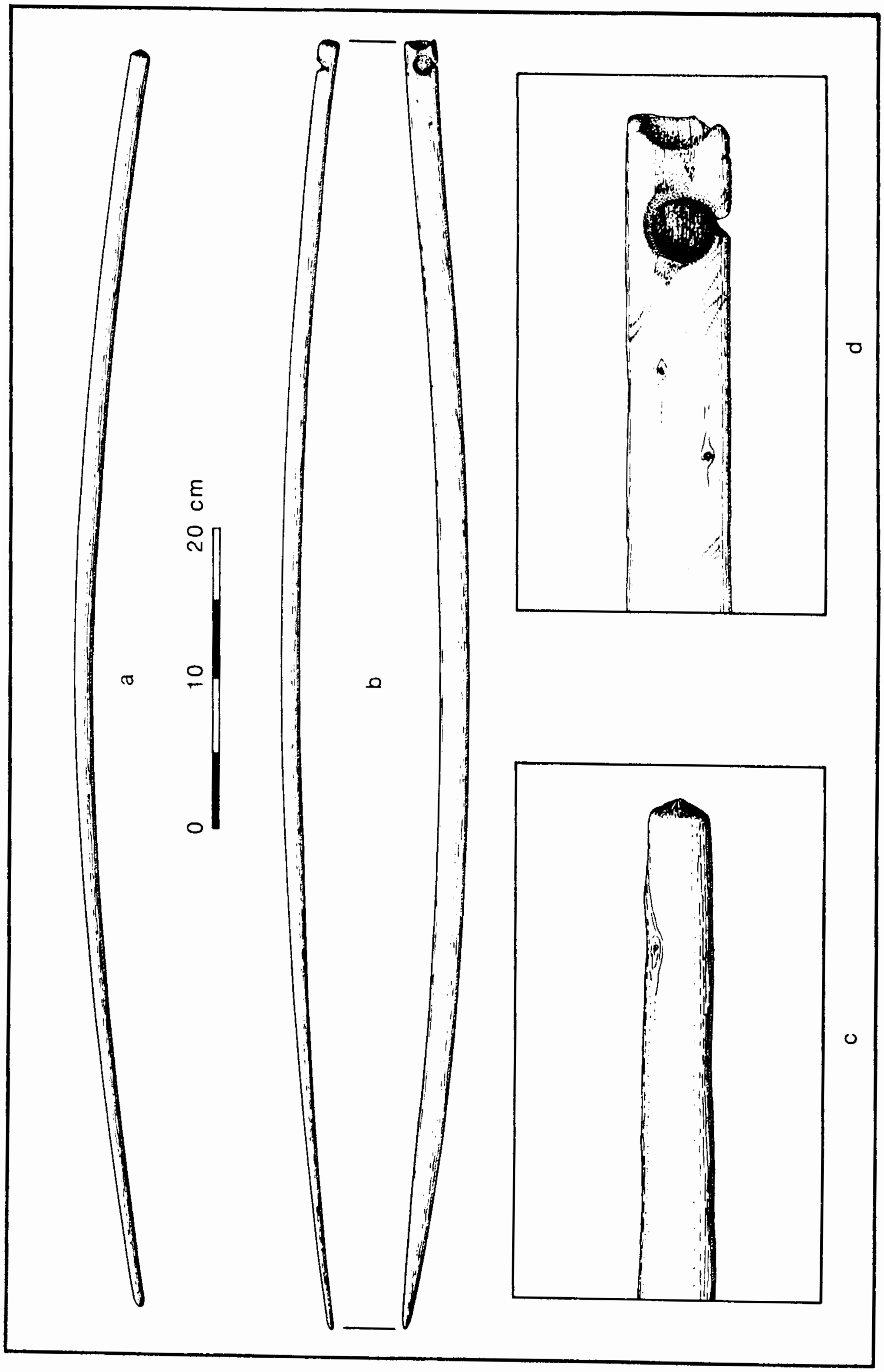

Figure 30. Fire drill and fire-drill hearth recovered from a rockshelter, site 42EM1722, near Oil Well Draw in the San Rafael Swell.

Given its length, this fire drill was probably twirled by hand rather than used with a bow.

The fire-drill hearth is made from a curved wooden shaft that appears to be part of a bow. It is subrectangular in cross section, measuring 84 cm long and a maximum of 1.5 cm wide (Figure 30b). One end tapers to a point; the other end contains two drilled holes. The shaft is broken in the middle of one hole, a hole which is drilled most of the way through the shaft. The second scar exhibits burning and is drilled only half way through the shaft. This scar is 1.1 cm in diameter and has a notch on one side to allow the embers to fall from the hole (Figure 30d). The drill and hearth fit together and were probably part of a single fire-making kit. Both items are now on display at the College of Eastern Utah Prehistoric Museum in Price, Utah.

Fire drills and/or fire-drill hearths have been recovered from a number of dry cave sites throughout Utah in Archaic, Basketmaker, Pueblo and Fremont contexts (Aikens 1970:170; Fowler 1963:66; Gunnerson 1969:153; Jennings 1957:190-191, 1980:81; Morss 1931:62; Steward 1937:19; Tipps 1983:106). The fire-drill hearth is similar to those recovered elsewhere in the state, although the others generally have much shorter shafts. Unlike the San Rafael specimen, most of the fire drills reported in the Utah literature are compound tools consisting of a drill foreshaft and a haft element. The length of the specimen from site 42EM1722 indicates that it was probably used without hafting.

The possible digging stick fragment was observed in a rockshelter, site 42EM1717, at the northern end of the San Rafael Swell. It consists of a worked wooden stick, 30 cm long and 2.5 cm in diameter. The tip is burned, perhaps to harden it, and is cut at an angle. This site also contained juniper bark and grass chaff throughout the fill, as noted in the side walls of several looters' pits. Site 42EM1716, a nearby rockshelter also contained vegetal remains throughout the fill.

A small bone pendant was noted in the midden at site 42SA14409 in the White Canyon study tract. The subrectangular pendant was made from a large mammal bone and was perforated at one end.

Euroamerican Artifacts

by Kenneth W. Russell

Euroamerican artifacts recorded during the survey include bottles and cans, generally found in historic or recent trash piles, and a variety of fairly recent trash including shotgun shells, shoes, fabric, wire-rimmed glasses frames, horseshoes, nails, car parts, dishes and other domestic items.

Several "purple" or amethyst glass bottles and fragments were found in Circle Cliffs and the San Rafael Swell, including canning and condiment jar fragments, a small jar with a snap-on lid and a St. Joseph's medicine bottle. Although purple glass was made from about 1880 to 1917 (Berge 1980:77-78), most of the purple bottle fragments found during the survey were produced by an automatic bottle maker which dates them sometime after 1904 (Berge 1980:77).

Clear and brown glass bottles and fragments, common after 1920, are also present on several sites. These include ketchup and mayonnaise jars, canning jars and medicine bottles, as well as liquor bottles with the post-prohibition label "Federal Law Prohibits Sale or Reuse of this Bottle." Two of the liquor bottles contain patent numbers which place them sometime between 1945 and 1960 (Richard Fike, personal communication).

Among the tin cans noted in the Circle Cliffs and San Rafael Swell study tracts are squat 2 lb, key-open coffee cans, in use from the 1920s to 1963; beer cans produced since 1935; modern sanitary cans common from 1910 on and soft drink cans produced after 1953. Several varieties of solder-dot evaporated or condensed milk cans were also noted. Most of the milk cans have the small matchstick filler hole that was introduced in 1885, but they are of an overall dimension that places them sometime after 1930 (Rock 1981b:10-11). One site in Circle Cliffs, site 42GA2572, contained hole-in-top milk cans with the larger 3/4" filler hole. These cans were produced by the Carnation Milk

Company between 1899 and 1918. Flat-sided, hinge-lidded tobacco tins, introduced around 1910 by the Velvet and Prince Albert tobacco companies, also occur on several sites.

Chapter 7

SITE DENSITY ESTIMATION

Introduction

Beginning with the writings of Binford in the the early 1960s, archeology moved from the descriptive stage toward stages of explanation and prediction (Willey and Sabloff 1980:189). Binford was critical of simple culture-historical descriptions and suggested that explanations for archeological data be sought within a systemic framework. He also called for greater use of general scientific methods and the implementation of statistical sampling strategies (Binford 1962, 1964). With the aid of computers, archeologists are now moving beyond pure description of archeological data to explanations of relationships and predictions of outcomes (Gardin 1980; Thomas 1974). This shift marks a turning point in archeology.

The objectives of this Class II inventory mirror the maturing status of archeology as a scientific discipline. For this project, the BLM required not only a description of the cultural resources within the study tracts, but explanations of why sites occur as they do and predictions about site frequency and location. The preceding chapters describe the results of this survey project and present preliminary explanations. This chapter and the next address the issues of predicting the frequency and distribution of cultural resources within the study tracts.

Site density varies considerably within the quadrats surveyed in the three study tracts. In Circle Cliffs, the frequency of prehistoric sites ranges from 0 to 6 per quadrat, while it ranges from 0 to 10 in the San Rafael Swell and 0 to 16 in White Canyon. In terms of average site density per quadrat, however, the San Rafael Swell has the lowest value with only 1.18 prehistoric sites per quarter section. Circle Cliffs and White Canyon have 1.77 and 2.86 sites per quadrat, respectively. Discussions in Chapter 5 identified some of the reasons for this variability in site frequency per quadrat, both within and between the three study tracts. Building on the results of the analysis reported in Chapter 5, the discussions in this chapter view the data from a different perspective, estimating the total number of sites in each study tract for management and planning purposes.

Site Density Projections

Estimation, the process of predicting population parameters based on a sample, is a necessary and complementary aspect of the statistical sampling procedure (Cochran 1963; Doran and Hodson 1975). For this project, it involves projecting the total number of sites in the project area based on a 10% inventory of that area. Of the two types of estimation, point estimation refers to predicting what would have been found had the entire population been studied, or in this case, the true number of sites in the project area. Interval estimation refers to calculating confidence intervals around the point estimate such that, under repeated sampling, this interval will contain the true value of the population parameter in a certain proportion of cases.

Interval estimation is necessary because point estimates are only rarely equal to the true population parameter; in other words, our estimate of the total number of sites in the study area would only rarely be exactly equal to the actual number of sites. The difference between the estimate and the real value is known as sampling error. But because the amount of sampling error cannot be determined without knowing the actual number of sites, it is desirable to calculate a confidence interval within which the parameter (i.e., the true number of sites) is likely to exist in a specific proportion of cases. This allows us to see how well the point estimate reflects the true population parameter and supplies the exact probability of error in the estimate (Blalock 1972:210).

To be of any value, the confidence interval should be (1) *precise*, that is, narrow relative to the magnitude of the quantity being estimated and (2) *reliable*, that is, likely to contain the true value of the parameter being estimated. The significance level, among other things, affects both the precision and reliability of the confidence interval. For example, a 95% confidence interval is narrower than a 99% interval, but less likely to contain the true value of the estimated parameter. Once a significance level is chosen, however, the narrower the interval, the more precise the estimate (Silk 1979).

An essential consideration in obtaining accurate, precise and reliable estimates is that the sampling design produce an unbiased and statistically representative data set. Thus, estimation is most effective when used with probability sampling, particularly a simple random sample (Asch 1975). The use of parametric estimation procedures on non-normally distributed data and/or samples obtained from complex sampling designs can have significant consequences on the resulting estimates (Kish 1957).

Evaluation of the Database

Before elaborating on the assumptions of estimation and calculating site density estimates, it is desirable to determine if the data from the first and second 5% samples in each study tract represent the same sampling universe so they can be combined for estimation purposes. While it is true that both 5% samples in each tract were selected from the same population of quadrats, it is possible that one of the samples is *unrepresentative* of the overall population.

A two-sample test, such as a *t*-test, is appropriate to evaluate whether two independent sample means were drawn from the same population. A nonparametric alternative to the *t*-test must be used for this case because even though the data meet the assumption of a simple random sample, they violate the assumption of a normal distribution (Figure 31). A Mann-Whitney U test is the most efficient nonparametric procedure available given the sample size (Siegel 1956:136).

The null hypothesis for Circle Cliffs is that there is no difference in the distribution of the number of sites per quadrat in the first and second 5% samples. H_1 states that the distribution of the number of sites per quadrat differs between the first and second 5% samples. Because we do not want to reject the null hypothesis in this instance, the significance level will be set at .15 to reduce the risk of a type II error, that is, failing to reject a false hypothesis (cf. Blalock 1972:162). Thus, the rejection region will consist of U values whose probability of occurrence is less than or equal to .15 under the null hypothesis. The test is two-tailed because H_1 does not predict the direction of the difference.

Mann-Whitney U values were calculated between the first and second 5% samples in Circle Cliffs following Siegel (1956:116-126). The probability of the U value obtained for Circle Cliffs is greater than 15% under the null hypothesis (Table 37). Thus, we can conclude that there is no significant difference between the first and second 5% samples in Circle Cliffs at the .15 level and that the samples can be combined for estimation purposes. The test for the San Rafael Swell yielded similar results (Table 37).

Assumptions

Standard formulas available for point and interval estimation assume a simple random sample, a normal distribution and a sufficiently large sample (Kish 1957:155-156; Silk 1979:152). As noted in Chapter 4, a simple random sample

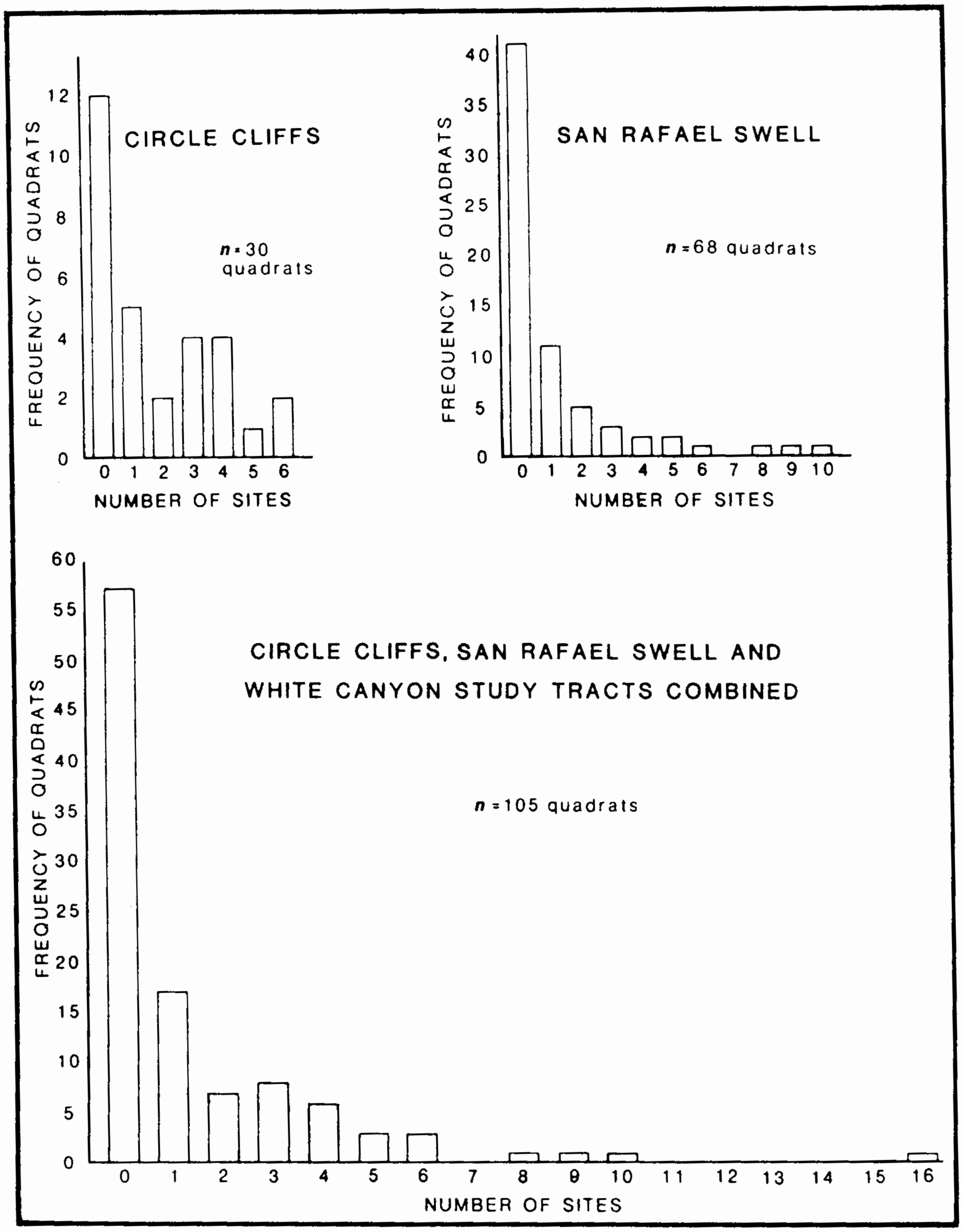

Figure 31. Bar graph of the frequency of quadrats by the number of sites showing the positively skewed distribution.

was used to facilitate calculation of population estimates and confidence intervals, among other reasons. Some clarification about the sampling design is appropriate here in light of the considerable confusion in the literature surrounding the differences between simple random and simple cluster samples (Mueller 1974). Much of this confusion results from the failure to recognize that the same sample can be considered simple random or simple cluster, depending on

Table 37. Mann-Whitney U data for the Circle Cliffs and San Rafael Swell study tracts.

Study Tract	n_1	n_2	U	p
Circle Cliffs	15	15	112.0	> .15
San Rafael Swell	34	34	506.0	> .15

NOTE: n_1 = number of cases in the smaller group; n_2 = the number of cases in the larger group; U = value of the Mann-Whitney U statistic; p = the probability of the U value in a two-tailed test. In this case, $n_1 = n_2$.

NOTE: Appendix 1 contains the raw data used to compute the Mann-Whitney U statistic.

how the research questions are framed (Nance 1983:297).

In order to distinguish between the two, it is necessary to identify the sampling unit and element of interest in the particular research problem. When the element of interest (i.e., the variable that is being analyzed, tested or estimated) is a characteristic of the sampling unit, the sample may be considered a simple random sample. In the present project where the sampling unit is the quadrat and not the individual site, examples would be the number of sites per quadrat, the number of Fremont sites per quadrat, or the number of features per quadrat.

If the element of interest is a characteristic of an entity within the sampling unit rather than the sampling unit itself, the sample is a simple cluster sample. Thus, if we wished to frame our research questions in terms of characteristics of the sites rather than characteristics of quadrats (i.e., our sampling unit), the sample would be a simple cluster sample. Examples would be analyses of site size, number of features per site or attributes of site location.

The other assumptions of a normal distribution and a sufficiently large sample require further discussion. As shown in Figure 31, all of the distributions are positively skewed, the result of spatial aggregation of the sites. Under the Central Limit Theorem, these samples may still be considered normal if the sample size is sufficiently large. What constitutes a "sufficiently large" sample depends on how closely the researcher wishes to estimate the probability of a type I error, and how closely the sampling distribution approaches a normal distribution, among other things (Blalock 1972:181-185). Cochran (1963:41) provides a "rule of thumb" formula for estimating adequate sample size when the principal deviation from normality is positive skewness. He states that when the sample size, n, exceeds $25G_1^2$, where G_1 is based on Fisher's measure of skewness,

$$G_1 = \frac{1}{n\sigma^3} \Sigma (x_j - \bar{x}_h)^3 \quad (7.1)$$

that the 95% confidence intervals will be correct at least 94% of the time. Table 38 shows that the samples in the San Rafael Swell and White Canyon study tracts are too small to justify parametric estimation procedures, whereas the 10% sample from Circle Cliffs is large enough to assume normality.

Because the 10% samples in two of the three areas were too small to apply the Central Limit Theorem (Blalock 1972:131), we decided to see whether the four 5% samples from Circle Cliffs and the San Rafael Swell could be combined to obtain a large enough sample. This combination was also desirable to create a sufficient sample to develop the model reported in the succeeding chapter. The White Canyon data were excluded because of the small sample size and the high degree of aggregation. The strong Anasazi influence in this area, which is lacking in the other areas, was another reason for separating this data set.

Table 38. Skewness values and sample size by study tract.

Study Tract	Skewness Value[a]	Requisite Sample Size ($n > G_1^2$)	Actual Sample Size
Combined 10% samples from Circle Cliffs and San Rafael Swell	1.97	> 97	98
Circle Cliffs 10% sample	0.82	> 17	30
San Rafael Swell 10% sample	2.47	> 153	68
White Canyon 10% sample	2.47	> 153	7

[a]Skewness values were computed using the CONDESCRIPTIVE program in the Statistical Package for the Social Sciences (SPSS [Nie et al. 1975]).

A *k*-sample test is appropriate to determine whether the four 5% samples from Circle Cliffs and the San Rafael Swell represent the same population with regard to site density. The Kruskal-Wallis One Way Analysis of Variance test is the most powerful statistic available for multiple groups of nonparametric data (Siegel 1956:194). The null hypothesis is that there is no difference in the number of sites per quadrat recorded in the four 5% samples from the Circle Cliffs and San Rafael Swell study tracts. The rejection region consists of all values of H that are so large that the probability associated with their occurrence is less than or equal to .15 under the null hypothesis with *k*-1 degrees of freedom. Because we want to retain the null hypothesis, the significance level is again set at .15 to reduce the risk of a type II error.

A Kruskal-Wallis test, corrected for ties, yielded an H value of 5.03 with three degrees of freedom (Hull and Nie 1979). The associated probability is greater than 15%, preventing rejection of the null hypothesis. Thus, the 5% samples from Circle Cliffs and the San Rafael Swell may be combined for estimation purposes and developing the predictive model. As shown in Table 38, combination of the Circle Cliffs and San Rafael Swell data creates a sufficiently large sample to assume normality. The raw data used to compute the Kruskal-Wallis test can be found in Appendix 1.

Computations

Appendix 1 contains the raw data necessary to compute density estimates for the project area, i.e., listings of the number of prehistoric and historic sites by quadrat for each study tract. Density estimates will only be computed for prehistoric sites, however, due to the extremely small number of historic sites. All formulas follow Cochran (1963) and/or Mendenhall et al. (1971).

The mean number of prehistoric sites per quadrat in the combined 10% samples from Circle Cliffs and the San Rafael Swell is

$$\bar{x} = \frac{\Sigma x_i}{n} \qquad (7.2)$$

$$= \frac{133}{98} = 1.36$$

where $\bar{x}$ is the mean number of sites in all quadrats, x_i is the count for element x in the *i*th quadrat and n is the number of quadrats surveyed. This value is an unbiased estimate of the true population mean.

The sample variance, an unbiased estimator of the variance of the estimated population parameter, is calculated by

$$s^2 = \frac{1}{n-1} \sum_{1}^{i} (x_i - \bar{x})^2 \qquad (7.3)$$

where s^2 is the sample variance, n is the number of survey quadrats, x_i is the count for element x in the ith quadrat and where $\bar{x}$ is the mean for element x in all quadrats.

The sample variance for Circle Cliffs and the San Rafael Swell is

$$s^2 = \frac{1}{98-1}(21.03)^2 = \frac{442.26}{97} = 4.56.$$

The estimated variance of $\bar{x}$ is calculated by

$$\hat{v}(\bar{x}) = \left(\frac{s^2}{n}\right)\left(\frac{N-n}{N}\right) \qquad (7.4)$$

where $\hat{v}$ = the estimated variance of $\bar{x}$ and N = the total number of quadrats in the sampling universe. Thus,

$$\left(\frac{4.56}{98}\right)\left(\frac{980-98}{980}\right) = .05(.9) = .04.$$

Once the point estimate of the population total (e.g., the mean number of sites per quadrat) and the variance have been obtained, the confidence interval can be specified by

$$\bar{x} \pm t\sqrt{\hat{v}} \qquad (7.5)$$

where t is the critical region for the normal curve in a two-tailed test with n-1 degrees of freedom. The confidence interval for the number of prehistoric sites per quadrat in Circle Cliffs and the San Rafael Swell is

$$1.36 \pm 1.99\sqrt{.04} = 1.36 \pm .41$$

at the .05 level of significance. Thus, we can conclude that, under repeated sampling, 94% of the estimates of the number of sites per quadrat would lie between 0.95 and 1.77.

Table 39 presents the results of similar calculations for prehistoric sites by 160-acre quadrat in each study area. Although the mean number of sites per quadrat obtained in the individual study tracts is probably relatively representative of the sampling universe, the confidence intervals for the San Rafael Swell and White Canyon should be viewed with caution because the data violate the assumption of normality, a violation which usually results in underestimation of the variance, and ultimately, inflation of the precision of the confidence interval.

Statistically speaking, the resolution of density estimates is limited to the size of the sample unit and should not be directly applied to larger areas as is commonly done; for example, estimating site density per square mile based on 40- or 160-acre quadrats. However, for comparative purposes, we may extrapolate the quadrat density estimates to obtain rough estimates of site density per square mile. In the combined Circle Cliffs and San Rafael tract, there would be an average of 5.4 sites per square mile, with 7.1 in Circle Cliffs, 4.7 in the Swell and 11.4 in White Canyon.

An estimate of the population total, that is, the total number of sites in the study area, can be obtained by

$$\hat{X} = \frac{N}{n} \sum_{1}^{n} x \qquad (7.6)$$

where $\hat{X}$ = the estimated population total, or more simply, by multiplying the total number of quadrats in the study area by the mean number of sites per quadrat $N(\bar{x})$. Thus, the total number of prehistoric sites in Circle Cliffs and the San Rafael Swell is estimated to be

$$980\,(1.357) = 1330.$$

The estimated variance of $\hat{X}$ can be calculated by

$$\hat{V}(\hat{X}) = N^2\left(\frac{N-n}{N}\right)\left(\frac{s^2}{n}\right) \qquad (7.7)$$

$$= (980)^2\left(\frac{980-98}{98}\right)\left(\frac{4.56}{98}\right)$$

$$= 960400\,(.9)\,(.05) = 40235$$

with confidence intervals being specified by

$$\hat{X} \pm t\sqrt{\hat{V}} \qquad (7.8)$$

Table 39. Estimation data for number of prehistoric sites by quadrat in the project area.

Study Tract	N	n	x	s^2	$\hat{v}$	$\bar{x}$	95% C.I.
Circle Cliffs and San Rafael Swell	980	98	133	4.56	.04	1.36	± .41
Circle Cliffs	300	30	53	3.84	.12	1.77	± .69
San Rafael Swell	680	68	80	4.83	.06	1.18	± .51
White Canyon	65	7	20	34.81	4.44	2.86	± 5.15

NOTE: N = the total number of quadrats in the sampling universe; n = the number of survey quadrats; x = the number of prehistoric sites; s^2 = the sample variance; $\hat{v}$ = estimated variance of $\bar{x}$; $\bar{x}$ = the mean number of sites per quadrat; 95% C.I. = the 95% confidence interval.

$$= 1330 \pm 1.99(200.59) = 1330 \pm 399.$$

The confidence interval can also be computed by multiplying the $t\sqrt{\hat{v}}$ value obtained for the quadrat variance by N, the total number of quadrats in the project area, thus by-passing the calculation of the estimated variance of $\hat{X}$. Hence,

$$\hat{X} \pm Nt\sqrt{\hat{v}} \qquad (7.9)$$

$$= 1330 \pm (980)(1.99)(.0419) = 1330 \pm 399.$$

Table 40 shows point and interval estimates of the number of sites in each study tract as well as the data needed to compute the estimation values. Based on these data, we project a range of 931 to 1729 prehistoric sites in the combined Circle Cliffs and San Rafael study tracts, 322 to 738 sites in Circle Cliffs, 456 to 1144 sites in the San Rafael Swell and 20 to 521 in White Canyon at the 95% confidence interval. Interval estimates for the San Rafael Swell and White Canyon study tracts are conservative and probably underestimate the confidence interval at the .05 level of significance because the samples are too small to assume normality given the amount of skewing and aggregation in the data. On the other hand, all of the estimates may somewhat *overestimate* the total number of sites in the study tracts because as Plog et al. (1978:395-400) note, archeologists generally record all sites that overlap into a survey quadrat.

Discussion

The precision, or width of the confidence intervals for the individual tracts, is somewhat disappointing—particularly in White Canyon where the confidence interval is larger than the value being estimated—although not surprising. The level of precision is directly related to sample size and could have been improved considerably with a larger sample (Cowgill 1975:263; Hole 1980:226; Plog 1976:151) (note the White Canyon interval versus the combined Circle Cliffs and San Rafael interval). Precision is also affected by the variance (equations 7.3 and 7.7), however, decreasing as the variance increases (Nance 1983:304). So what affects the variance? Among other things, it increases in direct proportion to increases in clustering or spatial aggregation of the sample elements (e.g., the sites). In our sample, the sample variance (s^2) exceeds the sample mean ($\bar{x}$) in all of the study tracts (Table 39), indicating that the sites are highly clustered. The clustering can also be verified by examining Figure 31 and by noting that all of the sites in Circle Cliffs are located in only 60% of the quadrats. In both the San Rafael Swell and White Canyon, roughly 40% of the quadrats contain all of the sites.

We can thus conclude that both the small sample size and the aggregated nature of the sites affected the precision of our confidence intervals. For future surveys, the precision could

Table 40. Estimation data for number of prehistoric sites in the project area.

Study Tract	N	n	x	s^2	$\hat{V}$	$\hat{X}$	95% C.I.
Circle Cliffs and San Rafael Swell	980	98	133	4.56	40236	1330	± 399
Circle Cliffs	300	30	53	3.84	10369	530	± 208
San Rafael Swell	680	68	80	4.83	29584	800	± 344
White Canyon	65	7	20	34.81	18747	186	± 335

NOTE: N = the total number of quadrats in the sampling universe; n = the number of survey quadrats; x = the number of prehistoric sites; s^2 = the sample variance; $\hat{V}$ = estimated variance of $\hat{X}$; $\hat{X}$ = the estimated population total; 95% C.I. = the 95% confidence interval.

be increased by (1) using a larger sample and (2) as more is known about the area, decreasing the variance by stratifying the area into subpopulations that are homogeneous with regard to site density. Of course incorrect stratification would have the undesirable effect of increasing the variance and decreasing the precision.

Comparisons

Comparisons of site density averages and estimates to those obtained for nearby projects are hampered because confidence intervals were not computed for other projects and the accuracy of the estimates is not known. These estimates can still be computed for some of the projects even though the results should be viewed cautiously due to problems with sample size and deviations from normality. They cannot be computed for other projects, however, because samples were drawn using complex sampling designs that are not adequately explained in the reports. As noted above, application of parametric estimation procedures to such data would probably result in underestimation of the confidence intervals.

In light of these problems, we believe that only general comparisons should be made between the results of our project and other surveys. Tables 41 and 42 present the average density of prehistoric sites per 160-acre quadrat for survey projects conducted near the project area. These averages are theoretically unbiased estimators of the population average in each study area. Only those projects using a 160-acre quadrat as the sampling unit are included to make the comparisons more valid.

The average number of sites per 160-acre quadrat in the Henry Mountain Planning Unit (Hauck 1979a) and Tract I of the Escalante Project (Kearns 1982) are within the 95% confidence intervals calculated for the Circle Cliffs tract. Those in the other areas are within the wider 99% confidence interval (Table 41). Although this minor variation may be cultural in origin, differences of such a small magnitude can be entirely attributed to sampling error caused by insufficient sample sizes and the use of stratified sampling designs. Other factors which may account for the small variation include differences in site definitions and the amount of spatial aggregation. One trend, however, appears to be the result of deliberate cultural selection. All of the tracts lying at higher elevations where the pinyon-juniper woodland is more abundant and dense (e.g., the Escalante Planning Unit, Alton Tract and Tract II) have a greater average site density than tracts lying at lower elevations in the desert

Table 41. Average density of prehistoric sites per 160-acre quadrat in project areas in and near Circle Cliffs.

Project	Number of Survey Quadrats	Number of Prehistoric Sites	$\bar{x}$	95% C.I.
Circle Cliffs 10% Sample	30	53	1.77	± .67
Central Coal Project Henry Mtn. Planning Unit (Hauck 1979a)	64	121	1.89	n/a
Southern Coal Project Escalante Planning Unit (Hauck 1979b)	72	197	2.74	n/a
Escalante Project Tract I (Kearns 1982)	25	34	1.36	± .75
Escalante Project Tract II (Kearns 1982)	46	118	2.57	± .97
Kane County Class II Alton Tract (Christensen et al. 1983)	20	54	2.70	± .97

NOTE: Confidence intervals were only computed for data sets obtained by a simple random sample. $\bar{x}$ = mean number of sites per quadrat; 95% C.I. = the 95% confidence interval.

shrub or mixed pinyon-juniper/desert shrub zone.

There is a great deal of variability in the average number of sites per 160-acre quadrat in survey projects conducted in and around the San Rafael Swell (Table 42). The average site density reported for only two of the five surveys, Summerville and Huntington, lie within the 95% confidence interval obtained in the San Rafael Swell study tract. Of the other three, only one lies within the wider 99% confidence interval. The other estimates are extreme relative to the average obtained in the San Rafael Swell and are probably the result of a number of factors. Like Circle Cliffs, some variation can be attributed to differences in site definitions and the use of disproportionate stratified sampling schemes. Evidently, however, much of the variation is a result of differences in the intensity of survey coverage (Richard Fike, personal communication), the small sample sizes and the large amount of site clustering. This clustering is of course cultural in origin and appears to be caused by the high degree of environmental variation in the general San Rafael Swell area. So, while the clustering and thus some of the variation may be culturally stimulated, the statistical result is a substantial increase in the width of the confidence intervals.

Table 42. Average density of prehistoric sites per 160-acre quadrat in project areas in and near the San Rafael Swell.

Project	Number of Survey Quadrats	Number of Prehistoric Sites	$\bar{x}$	95% C.I.
San Rafael Swell 10% Sample	68	80	1.18	± .50
Central Coal Project Muddy Planning Unit (Hauck 1979a)	22	50	2.27	n/a
Central Coal Project Summerville Planning Unit (Hauck 1979a)	15	19	1.27	n/a
Central Coal Project Huntington Planning Unit (Hauck 1979a)	10	7	0.70	n/a
Central Coal II Tract II (Thomas et al. 1981)	31	7	0.22	± .17
Central Coal II Area 3 (Thomas et al. 1981)	11	101	9.18	± 3.92

NOTE: Confidence intervals were only computed for data sets obtained by a simple random sample. $\bar{x}$ = mean number of sites per quadrat; 95% C.I. = the 95% confidence interval.

Chapter 8

SITE LOCATION AND PREDICTIVE MODELLING

by Alan R. Schroedl

One of the main objectives and requirements of this project was to develop a predictive model of site location for management needs and research purposes. Two separate models were developed to meet this obligation. The first, derived through a multivariate analysis of map-readable environmental variables, predicts site presence and absence by 160-acre quadrat and was developed for the combined Circle Cliffs and San Rafael Swell data set. As required by the contract, this multivariate model was developed using the data from the first 5% sample inventory and tested with the data from the second 5% sample. It was refined for greater predictive accuracy by discarding three outlying quadrats and increasing the size of the training set, and again tested with the remaining quadrats. From these results, a final model was then developed using the entire combined 10% sample.

In the second modelling effort, Landsat imagery data were analyzed by a variety of multivariate techniques to delineate several "environmental" strata within the study area. The validity of these strata was subsequently confirmed using discriminant analysis. Following this, the probability of a quadrat having sites was derived for each environmental stratum by dividing the observed number of quadrats with sites in the particular stratum by the total number of quadrats. Separate Landsat models were developed for the Circle Cliffs and San Rafael Swell study tracts.

The multivariate analysis was conducted by P-III Associates' staff and is detailed in the sections below. The Landsat models were developed by the University of Utah Archeological Center and are reported in Appendix 8. The results of both modelling efforts are described and compared at the end of this chapter.

Assumptions of Site Locational Modelling

Most models of site location are predicated on some implicit assumptions that are important for understanding the overall results and significance of the work. Thus, before explaining the development of the model, we wish to specify our assumptions to set the context for interpreting our site locational efforts.

First and foremost, we assume that sites are *not* randomly or uniformly distributed across the study tracts but are clustered, presumably in response to the availability of critical resources. This assumption has been demonstrated by a variety of researchers and shown to be true for the study tracts included in the present analysis (Chapters 5 and 7). Second, we assume that the nonrandom nature of site distribution, the dependent variable, is not correlated within any *single* environmental or cultural variable. That is, no one factor can explain the presence or absence of all sites in any given region. Following from the second assumption, we also assume that there are a multitude of cultural and natural factors that influence and correlate with site location. Thus, some form of multivariate analysis is necessary to develop a model that reflects these varying factors and accurately predicts site location.

One assumption we do not make is that correlation signifies causality. Although correlations may exist between certain environmental or cultural variables and site locations, this does not imply that the variables "cause" site locations to be selected. Thus, while it may be possible to correlate certain environmental features with site location, a thorough explanation of these correlations requires complementary evidence derived from theoretical models and ethnographic analogy.

The goal of the present analysis is to identify a small set of quantifiable and measurable environmental variables that can be used to explain a high percentage of the variability in the site distribution in the study tracts and to predict site locations in the uninventoried areas. This approach focuses on correlations between site locations and environmental parameters and does not directly attempt to *explain* the nature of site distribution. However, the subjective assessments and explanations of critical site location factors discussed in Chapter 5 compliment the results of this modelling effort.

Selection of a Multivariate Procedure

Although there are a variety of multivariate analytical techniques that can be applied to complex data sets (Cooley and Lohnes 1971; Morrison 1976; Tatsouka 1971), those that have been used for site locational modelling can be considered special cases of general linear regression models.

The general procedure for such linear models involves determining a set of coefficients, v_1, v_2, ..., v_p, that are multiplied against some set of independent variables, X_1, X_2, ..., X_p, such as environmental variables, so that Y, the dependent variable, usually site presence/absence, is reproduced as closely as possible to the original observation, i.e., the actual presence or absence of a site. For the *i*th case, the general linear model is

$$Y_i = \Sigma v_i X_{ji} + \varepsilon_i$$
$$= v_1 X_{1i} + v_2 X_{2i} + \dots + v_p X_{pi}\, \varepsilon_i$$

The factor ε_i is an error term or disturbance factor and is generally ignored as measurement error in Y or considered representative of the incompleteness of the model. This model becomes multivariate when Y is a vector variable with a number of different outcomes, each produced by a different set of *p* coefficients for the set of *p* variables. For example, most site location models predict one of two possible outcomes: site presence or site absence. For each significant variable in the equation there are two sets of coefficients, one for the group with sites and one for the group without sites.

Several multivariate linear procedures have been applied to predicting site locations – multiple regression (Green 1973; James et al. 1983; Nance et al. 1983), logistic regression (Holmer 1982; Kvamme 1983a; Lafferty et al. 1981; Parker 1983) and discriminant analysis (Brown 1979; Creasman 1981; Holmer 1979, 1982; Kvamme 1980, 1983b; LaPoint et al. 1981; Larralde and Chandler 1981; Parker 1983; Peebles 1981; Zier and Peebles 1982). The structure of the data set and the goal or purpose of the analysis dictate which procedure is appropriate.

For multiple regression, the coefficients are derived by minimizing the difference between the observed and predicted value of Y. Using the site presence/absence example, the coefficients for all of the environmental variables would be derived so that locations without sites would have a computed value of 0 and locations with sites, a computed value of 1, at least as much as possible.

Parker (1983) argues that this is not an appropriate approach to site location prediction. Multiple regression requires that the dependent variable have an underlying continuous distribution. If a binary variable such as site presence or absence is used, the coefficients will have an unbounded continuous range rather than predicted values of 0 or 1. She suggests that other methods such as logistic regression would be more appropriate for predicting site presence/absence.

Logistic regression and discriminant function analysis are two other multivariate procedures that have been used to develop site location models. When certain statistical assumptions are met, such as continuous interval level variables with joint multivariate normal distributions and equality of the covariance matrices, discriminant functions are more efficient than logistic regression functions (Knoke 1982:194; Parker 1983).

However, site location data do not always meet these requirements. In cases where the covariance matrices are not equal, quadratic discriminant analysis is more appropriate than linear discriminant analysis. In other cases where normality cannot be assumed and some of the independent variables are binary or discrete, logistic regression analysis is more successful than discriminant analysis (Press and Wilson 1978).

Logistic regression appears to be well suited for predicting site presence or absence because it predicts actual probability of membership to a binary class, i.e., site presence or absence. However, logistic regression can only be used to separate cases into two dichotomous groups, e.g., locations with sites and locations without. If the problem calls for a three- or more group solution, such as locations without sites, locations with a few sites and locations with many sites, discriminant analysis is more appropriate because it allows the researcher to simultaneously study differences between more than two groups with respect to a number of variables (Klecka 1980:7).

Discriminant analysis differs from logistic regression and multiple regression in that coefficients for the functions are not derived to minimize the difference between the observed and expected values of Y but rather to maximize the difference of the ratio of group means to the group variance between groups. In essence, for any number of groups, the discriminant function coefficients are derived by maximizing the ratio of the between-groups variance-covariance matrix to the within-groups variance-covariance matrix (Tatsouka 1971:157-161). Thus, for site prediction, discriminant analysis attempts to find a series of functions that will provide the maximum statistical separation between locations with sites and locations without sites. Not all of these derived functions may be statistically significant because the first few functions may explain the major percentage of variation.

Although archeological data rarely meet the assumptions of discriminant analysis, as noted above, Knoke (1982:199) notes that the procedure is very robust and can still provide accurate classification information. Because of the robust nature of discriminant analysis and its ability to simultaneously derive classification functions for more than two groups, discriminant analysis was selected as the multivariate procedure for this predictive modelling effort.

Overview of Discriminant Analysis

In order to understand the results of our modelling effort, it is necessary to provide some background information on discriminant analysis. Discriminant analysis is a procedure for deriving functions which are linear combinations of variables such that these functions result in the maximum statistical separation between two or more predefined groups. These functions can be used to develop classification coefficients which can assign an unknown case to one of the predefined groups.

The discriminant analysis for this model was conducted using SPSS subprogram DISCRIMINANT (Nie et al. 1975). This program provides a variety of output that can be used to evaluate the importance of the variables and the the validity of the derived functions. Some of the intermediate results of this program are discussed below in relation to predictive modelling.

In the context of most site locational modelling, a series of variables that are believed to be correlated with site location (e.g., distance to water, slope, elevation, etc.) as well as the predefined group classification (e.g., locations with sites and locations without) are entered into the analysis for each case. At this point, a cursory comparison of the mean and variance for any variable in relation to the two groups will suggest whether or not the variable will be important in the discriminant function. The greater the difference between group means for a variable, the more likely it will be useful in distinguishing locations with sites from locations without sites.

However, computation of the univariate F-ratio is a more accurate method of evaluating the statistical significance of the variable. Cast in the light of hypothesis testing, the researcher can choose an appropriate significance level (e.g., .01, .05, etc.) and set up a null hypothesis that there is no difference between locations with sites and locations without sites for the variable. The researcher then compares the derived F-ratio with the expected F-ratio for the appropriate degrees of freedom. If the computed F-ratio exceeds the specified level, then the researcher can reject the null hypothesis and assume that there is a significant difference in the variable between the two groups.

Alternatively, the F-ratio can be interpreted on a scale of importance in discriminating between the two groups. The larger the F-ratio for a variable, the more important it will be in distinguishing between locations with sites and locations without. In fact, in a stepwise discriminant analysis, the variable with the largest univariate F-ratio is the first variable entered into the function.

In the discriminant procedure, the variables can be entered into the analysis as a group or in a stepwise fashion. Generally, site prediction efforts have used the stepwise procedure because it results in maximal separation between groups. The direct method may yield less separation because of interactions between variables. For example, site location may be correlated with both elevation and vegetation zone. However, these two variables may be correlated among themselves, which can reduce the effectiveness of the discriminant function. Thus, a function incorporating all variables may have less discriminating power than one that uses only a subset of the variables.

Stepwise inclusion segregates the groups by entering one variable at a time according to its ability to further distinguish between locations with sites and those without. The variable with the greatest univariate F-ratio is the first to be entered into the analysis. After this variable is entered into the procedure, an "F-to-enter" value is calculated for each remaining variable. The next variable to be entered into the procedure is the one with the largest "F-to-enter" value.

During each succeeding step, the remaining variables are evaluated and entered into the equation based on their ability to further segregate the groups. At each step, variables already entered into the equations are tested to determine whether they continue to contribute in distinguishing between the groups. If a variable no longer contributes to the ability of the function to discriminate between groups, it is removed from analysis at that time.

A stepwise procedure generally results in a subset of the original variables being selected for the function, which is another reason why it has been preferred over the direct method. The prediction of site locations in uninventoried areas requires that each of the significant variables be measured and entered into the classification functions. If only a few of the original variables can adequately distinguish locations with sites from locations without sites, then the model is more practical for use in a management setting because less encoding is required.

For the modelling effort presented below, a stepwise method which maximizes Rao's V was used as the selection criterion to enter variables into the equation. The result of this stepwise procedure is a set of coefficients that maximize the difference of the group centroids without reference to the internal cohesiveness of the group (Klecka 1980:54).

These discriminant function coefficients are standardized and thus the importance of each variable in the function can be readily evaluated. The larger the absolute value of the coefficient for a variable, the greater its contribution to the function and the discrimination between groups. The sign of the coefficient indicates whether its contribution is negative or positive relative to the sign of the centroid value of each group.

The procedure of variable selection using stepwise inclusion is the same for any number of groups in the analysis. But as the number of groups increases, so does the number of derived functions. The number of derived functions will generally be equal to one less than the number of groups in the analysis.

The interpretation of each of the coefficients for each function is the same. However, there is an important aspect that must be noted when more than one function is derived. The first discriminant function always explains as much of the variation as possible between the groups. The second and succeeding functions explain the variance that was *not* explained by the previously derived function or functions. This means that each function explains a different dimension of variation.

The functions are derived so that the discriminant criterion or eigenvalue is maximized. One eigenvalue is derived for each function. When there is more than one function, the ratio of each eigenvalue to the sum of all of the eigenvalue indicates the relative importance of any particular function. But because of the manner in which the functions are derived, the eigenvalue will decrease for each succeeding function.

Two measures can be used to evaluate the usefulness or significance of the derived discriminant functions. One, the canonical correlation, is a measure of the relationship between the derived function and the groups. It can be computed for a particular function by dividing the eigenvalue by one plus the eigenvalue and taking the square root of the quotient (Klecka 1980:36). In general, the higher the canonical correlation for a given function, the more powerful the function in discriminating between the groups.

The square of the canonical correlation has a more intuitive interpretation because it is the proportion of variation in the function explained by the groups (Klecka 1980:37). In the context of site prediction, the squared canonical correlation can be thought of as the amount of variation between locations with sites and locations without sites that is explained by the function.

Another measure that can be used to evaluate the significance of a function is the matrix of pairwise F-ratios. Such a matrix can be computed at each step in the analysis as variables are entered or removed from the function. This matrix presents the associated F-ratio for each pair of groups in the analysis. The researcher can then evaluate, in terms of a significance test, whether or not the difference between the centroids of each pair of groups is significant or could be obtained by chance.

Assuming that the function or functions are significant, a series of classification coefficients can be derived which can then be used to classify unknown cases into one of the predefined groups. That is, measurements for the significant variables from an unsurveyed location can be entered into these functions to determine whether it belongs to the group with sites or the group without sites.

There are two ways to classify such unknown locations. The first involves the use of unstandardized discriminant classification coefficients. This procedure has the advantage of allowing the researcher to calculate both how far the unknown case is from the centroid of each group and the exact probability of it belonging to each group. This method and its application to site location prediction are described by Larralde and Chandler (1981:234-237).

A second and more straightforward method uses the simple classification functions to determine group membership for unknown cases (cf. Klecka 1980:43). While the function coefficients for this method have no interpretive value, they are easier to use than the discriminant classification coefficients for classifying unknown cases and would therefore be useful for management purposes.

To apply this method, the values of each variable for the unknown case are multiplied by the classification coefficients and then summed along with the constant for each function. The unknown case should then be assigned to the group corresponding to the function with the highest classification score.

The computation for both classification functions, the discriminant classification functions and the simple classification functions are similar. The difference between the two approaches is that for the discriminant classification function, the results have to be compared with the values of the group centroids to determine to which group the unknown case should be assigned. For the simple classification functions, the researcher identifies the largest value and assigns the case to that group. There is no need to refer to the value of the group centroids. In the succeeding sections, we will present the simple classification functions as they are more amenable to management purposes.

The final test of the usefulness of the derived functions is how well they can distinguish, in actual practice, locations with sites and locations without. Usually, a researcher obtains a table showing the number of correct and incorrect group classifications and an overall correct rate of classification. These tables represent the application of the functions to the data set from which the functions are derived, and hence, represent rates of self-classification.

Morrison (1969) notes that these self-classification rates are upwardly biased, that is, they overestimate the true ability of the functions to correctly classify cases. It is for this reason that he and other researchers suggest that the functions be tested against independent, randomly derived data sets. The structure of the data set for this project allowed us to test the predictive functions we derived in the initial analysis using a split sample validation technique. Split sample validation refers to testing a model with an independent data set derived from the same sample population by the same sampling procedure as the training set.

The Discriminant Function Model

Discriminant analysis was used to develop a multivariate model based on map-readable environmental variables. As noted in the introduction to this chapter, the first 5% sample was used as a training set to develop a discriminant function. The function was then tested against the second 5% sample, the validation set. The results of this effort were refined and a larger training set was used to test the model again. The final refinement of the model included all of the data as a training set and a series of final functions were derived.

Selection of Spatial Resolution and Sample Size

Site prediction models can be ranked or scaled according to the degree of resolution or the size of the area for which the prediction is made. We define high-resolution models as those that predict actual site presence or absence at a specific location. These modelling efforts can be defined as "point prediction models." Medium resolution models, as we define them, are used to predict site presence or absence in areas of varying size, such as 20-, 40-, or 160-acre quadrats or transects. Such high and medium resolution models are generally multivariate, that is, the probability of a particular location or area having a site is predicted based on the intersection of a number of variables.

Although site specific, point location models have been implemented more frequently than medium resolution quadrat models (cf. Chandler and Nickens 1983; Creasman 1981; Kvamme 1980, 1983a, 1983b, 1983c; LaPoint et al. 1981; Larralde and Chandler 1981), we have chosen to use 160-acre quadrats as our unit of analysis for several practical and theoretical reasons.

The first and most important reason is the measurement error that would be introduced using a smaller unit of analysis. Twelve of the 15 maps which cover the study area are currently only available at the 15-minute scale, with 40- or 80-foot contours. On these maps, the 160-acre study unit covers a square only 12.5 mm on a side, yet a number of quadrats contain many sites, and one even contains 16 sites. Because of the small scale of the maps and the high number of sites per quadrat, we believe that the measurement error would appreciably affect the within group variance for both site and nonsite locations and that it would offset much of the increased accuracy that might be gained from a finer resolution model.

Second, medium resolution models such as a quadrat model can often provide predictive results that equal or exceed finer resolution models with less expenditure of time and effort. Point location models generally involve a greater investment of time and labor than quadrat models to measure and encode the data, particularly for large surface areas (Kvamme 1983c; Zier and Peebles 1982:226).

For example, Kvamme (1983c:155), using a point model, had to measure six variables for 256 point locations (more than 1500 measurements) to derive probabilities of site presence for a single quarter section – *160-acres*. Kvamme (1983a) discusses several computer programs that can read and encode digitized terrain maps to overcome the problem of hand-encoding large amounts of data. However, until these programs are generally available and implemented for researchers and land managers, hand-encoding of these variables will continue to be necessary. Clearly, such labor intensive measurement is not cost effective if a relatively successful predictive model can be derived with fewer hand-encoded measurements by use of a medium resolution model.

Third, Klecka (1980:51) and Morrison (1969:157), among others, note that the classification functions can only be tested with independent data sets. And, if the derived functions are to have any general applicability to the larger population, in this case the other 90% of the study tracts, the test data should be collected by a random sample (Cooley and Lohnes 1971:262). In the sampling design established by the BLM for this project, the quadrats are the sampling unit and hence they, not the sites, were selected by a simple random sample. If we wish to study the environmental attributes of site and nonsite locations in the context of the present sampling design, the sample of sites and nonsites would have to be considered a cluster sample rather than a random sample (see Chapter 7 and Nance 1983). The validity of deriving and testing classification functions using cluster samples is questionable and the applicability of such functions to the unsurveyed portions of the study tracts is problematical.

Finally, in study areas such as Circle Cliffs and the San Rafael Swell where sites are highly clustered, a quadrat model can more accurately identify locations of site clusters than a point model. The final, refined, three-group quadrat model presented below is able to statistically distinguish between three classes of quadrats, those without sites, those with only one site and those with two or more sites. This final model was able to correctly identify over 90% of the quadrats with sites, a rate that equals or exceeds those obtained by point location models.

Thus, the groups in our discriminant analysis are quadrats with sites and quadrats without sites. While the sampling fraction for this project was 5% for each of the two phases of the inventory, the actual number of survey quadrats, or sample size, was only 105 quadrats spread between three geographically separated study tracts. Because the sample size was minimal in all three areas, it was not possible to develop independent predictive models for each tract, nor was it required by the BLM. In Chapter 7, we demonstrated that the samples from the San Rafael Swell and Circle Cliffs are statistically similar and that they can be combined to obtain a large enough sample for the split sample validation in the predictive modelling effort.

The White Canyon study tract was excluded from both the discriminant analysis and the Landsat modelling because it had only seven quadrats and because the sites in this area are primarily Anasazi habitation sites while those in the other areas are primarily field camps and base camps. However, Chapter 5 discusses some of the critical variables that will be useful in developing site location models when a larger sample is available in the White Canyon study tract.

The predictive modelling efforts are based on the results of the survey of 30 quadrats in the Circle Cliffs tract and 68 quadrats in the San Rafael Swell study tract. As noted above, the quadrats from both areas were grouped by sample phase. Forty-nine quadrats, 15 from Circle Cliffs and 34 from the San Rafael Swell, were included in each 5% sample. Table 43 presents the sample size and distribution of quadrats with sites and without sites for each sample.

Selection of Variables

Although there are an infinite number of variables that could be used to develop a site location model, i.e., to distinguish between locations

Table 43. Sample size of quadrats with sites and quadrats without sites by sample.

Group	First Sample	Second Sample	Total
Quadrats with sites	29	25	54
Quadrats without sites	20	24	44
Total	49	49	98

with sites and locations without, there is a practical restriction on the variables that can be selected if the model is going to be used to predict site location in unsurveyed areas. In this case, it must be possible to measure the variables from a map or other sources that do not require on-site field visits.

Obviously, this limitation causes most researchers to resort to "map-readable" variables for predictive modelling. Water resources are coded as distance to water and measured vertically and horizontally off a map from a site location to a marked spring, river, or intermittent or perennial drainage. Vegetation variables are measured from vegetation maps or as distance to a wooded area on the map. Relief and elevational changes are determined from contour lines, etc.

Building on the results of the the environmental correlations identified in Chapter 5 and the results of previous modelling efforts, we selected nine map-readable and measureable variables that have been shown to be correlated with site presence/absence. All were measured from the largest scale maps available for each quadrat. These variables are

1. Quadrat relief in m (RELIEF). This variable was defined as the difference between the maximum and minimum elevation within the quadrat.
2. Quadrat elevation in m (ELEVATION). Quadrat elevation was calculated by summing the maximum and minimum elevation of the quadrat (see RELIEF) and dividing by two.
3. Distance to the nearest river in km (DISTANCE TO RIVER). This distance was measured in a straight line from the center of the quadrat to the nearest river. In the Circle Cliffs study tract, measurements were made to the Escalante River. The San Rafael and Muddy rivers were used for the San Rafael Swell tract.
4. Distance to nearest permanent water in km (DISTANCE TO WATER). This distance was measured from the center of the quadrat to the nearest spring or river identified on the topographic maps.
5. Percent of quadrat covered by pinyon-juniper vegetation (QUADRAT COVER). The percent of the quadrat covered by green shading on the topographic map was separated into five groups. Quadrats with no green shading were assigned a value of zero. Quadrats with between 1% and 25% green shading were assigned a value of 12%. Those with 26% to 50% shading were assigned a value of 37%. Sixty-two percent was assigned to quadrats that had 75% or less shading but more than 50% shading. Finally, quadrats with 76% to 100% shading were assigned a value of 87%. The results of the analysis indicate that greater predictive accuracy might have been obtained if QUADRAT COVER had been coded as a continuous variable.
6. Distance to wooded area in km (DISTANCE TO WOODED AREA). This distance was measured from the center of the quadrat to the closest green-shaded area on the topographic map. The value was zero when the center of the quadrat was shaded.
7. Number of drainages within the quadrat (DRAINAGES). This variable is the number of blue line drainages present within a quadrat as determined from the topographic map.

8. Cosine of quadrat aspect (ASPECT-COS). Quadrat aspect was defined as the azimuth off true north of a line drawn from the highest point on the quadrat to the lowest. Kvamme (1980:116) notes that the compass scale must be transformed or locations with similar aspects may have numerically divergent azimuth readings. Kvamme "collapses" the west half of the compass scale over the east half so that all aspects maintain the relative north/south exposure. Instead of Kvamme's approach we have used the cosine of the azimuth. Both transformations produce identical scaling results and maintain the relative north/south exposure.

9. Sine of the quadrat aspect (ASPECT-SIN). Although Kvamme's aspect transformation and the cosine transformation used above maintain the variability in north/south aspect, both procedures lose the variability in east/west exposure. Because we wished to see if relative east/west exposure was important in site location, we used the sine of the aspect to reflect this variable. By using both sine and cosine transformations of the aspect, we have maintained measures of both the east/west and north/south exposure of the quadrat (Roise and Betters 1981).

Development of the Initial Model

The initial discriminant analysis was performed on the first 5% sample using two groups, quadrats with sites and quadrats without sites, and nine variables. The quadrats in the first 5% sample, 15 from Circle Cliffs and 34 from the San Rafael Swell, were combined and used as a "training" sample for the discriminant analysis. The mean and univariate F-ratio are presented in Table 44. At the .05 level of significance, QUADRAT COVER is the only significant variable.

Since only two groups were included in the analysis, only one discriminant function was produced. The stepwise inclusion procedure included only four variables, RELIEF, DISTANCE TO WATER, QUADRAT COVER and NUMBER OF DRAINAGES, in this function because the other five variables did not significantly contribute to the functions' discriminating ability.

The standardized discriminant function coefficients for each of the variables included in the solution are presented in Table 45. The coefficients of each of these variables indicates the relative contribution of the variable in computing the discriminant score for a particular case. Quadrat cover is the most important variable for this analysis, followed by distance to water. Quadrat relief and the number of drainages in the quadrats are less than half as important as the amount of pinyon-juniper in the quadrat and the distance to permanent water. This function implies that for any quadrat the more pinyon-juniper cover and the greater the number of drainages, the more likely the quadrat will have sites. The greater the relief and the farther from permanent water, the less likely the quadrat will contain sites.

The four discriminating variables produced a small eigenvalue of .26 with a canonical correlation of .46, explaining only about 20% of the variance. The classification function for the data set was applied to the 49 quadrats used to derive the function, and a self-classification rate of 73% was obtained (Table 46). This classification rate and the eigenvalue and canonical correlation are well within the range of values from other predictive modelling efforts and can be considered minimally successful (Table 47).

Validation Test of the Initial Function

While the discriminant function based on the first 5% sample is statistically significant and can certainly be considered successful relative to previous projects, a more accurate assessment of the predictive power of our discriminant function can be derived by applying it to an independent data set. Most researchers use the self-classification rate as a measure of the model's predictive power. However, as noted previously, these self-classification rates are upwardly biased because they are computed for the same data set that was used to derive the function. The true test of any site prediction

Table 44. Group means and univariate F-ratios for variables in first data set based on 50 quadrats.

Variables	Quadrats without Sites	Quadrats with Sites	All Quadrats	Univariate F-ratio
RELIEF	102.1724	81.9500	93.9184	1.1678
ELEVATION	1823.2759	1901.1500	1855.0612	2.3162
DISTANCE TO RIVER	16.1138	14.5250	15.4653	0.3764
DISTANCE TO WATER	5.0552	3.8500	4.5633	1.1130
QUADRAT COVER	20.0345	42.2000	29.0816	4.7356
DISTANCE TO WOODED AREA	0.8000	0.4200	0.6449	3.1563
DRAINAGES	0.6552	0.8500	0.7347	0.8413
ASPECT-SIN	-0.0078	-0.0838	-0.0388	0.1304
ASPECT-COS	-0.1996	-0.2554	-0.2224	0.0795
Sample size	29	20	49	

Degrees of freedom for univariate F-ratio: 1, 47

Table 45. Standardized coefficients, eigenvalue, canonical correlation and pairwise F-ratio for the discriminant functions based on the first 5% sample.

Variable	Coefficient
RELIEF	.3314
DISTANCE TO WATER	.6831
QUADRAT COVER	-.8365
DRAINAGES	-.3601
Eigenvalue	.263
Canonical correlation	.456

Pairwise F-ratio for 4 and 44 degrees of freedom = 2.89

Table 46. Classification results of the initial model.

Actual Group Membership	Predicted Group Membership: Quadrats with Sites	Quadrats without Sites
Quadrats with sites	21	8
Quadrats without sites	5	15

36 of 49 quadrats correctly classified - 73%

Table 47. Comparison of results of previous discriminant analyses for site location prediction.

Project	Eigenvalue	Canonical Correlation	Percent Correct Classification
Split Mountain, UT (Holmer 1979)	not reported	not reported	76%
Glenwood Springs, CO (Kvamme 1980)	.86	.68	85%
Seep Ridge, UT (Larralde and Chandler 1981)	1.12	.73	88%
Douglas Creek, CO (LaPoint et al. 1981) (mainstem)	.13	.34	66%
Douglas Creek, CO (LaPoint et al. 1981) (transect)	.66	.63	76%
Kemmerer, WY (Zier and Peebles 1982)	.17	.38	70%
Kolob-Alton, UT (Christensen et al. 1983)	.70	.63	80%

model is its ability to correctly classify locations from an independent, randomly derived data set.

The two-phase sampling procedure of this project was specifically designed to provide such an independent, random data set. The procedure of testing a function with an independent data set derived from the same population by the same sampling scheme as the training data set is referred to as split sample validation (Klecka 1980:51). This procedure allows the most accurate assessment of the strength of the model.

When applied to the second 5% sample, the classification functions correctly classified 16 (64%) of the 25 quadrats with sites and 15 (64%) of the 24 quadrats without sites. This is an overall correct classification rate of 63%, a 10% decrease in the accuracy under the self-classification rate. This decrease is not surprising because researchers generally experience a decrease in accuracy (an increase in the error rate) on the validation data set (cf. Press and Wilson 1978:Tables 1-2).

How does this error rate compare with other predictive models that tested their functions against an independent, random data set? Only a few site prediction efforts have attempted to validate their results and none of these efforts used independent random data.

On the Glenwood Springs project, Kvamme (1980) tested his classification function on a series of site and nonsite locations from a previous survey and was able to correctly classify

80% of the locations. On a more recent project near Grand Junction, Colorado, Kvamme (1983c:103,104) tested a derived logistic regression function and was able to correctly classify only 63% of the site and nonsite locations. On the Canyon Pintado project, LaPoint et al. (1981:IV-3) tested a discriminant function derived from site and nonsite locations along the mainstem of Douglas Creek against a series of site/nonsite locations from a transect survey. They obtained a correct classification rate of only 58% on the test data.

For the Seep Ridge project, Larralde and Chandler (1981) conducted a discriminant analysis based on 34 site and 68 nonsite locations and applied their function to a group of 98 previously recorded sites in and near their project area. They achieved a 53% correct classification rate. Because of the poor results, they developed another model based on the 98 previously recorded sites and the 68 nonsite locations used in the initial analysis. The classification function from this analysis was tested with the 34 site locations recorded during the Seep Ridge inventory. The 91% correct classification results of the validation test are difficult to interpret because it appears that more than 50% of 98 site locations in the training sample are outside of the the Seep Ridge study tract, while all 68 nonsite locations in the training set are within the study tract. Additionally, nonsite locations were not included in the validation test which would have probably increased the overall error rate.

The results of our validation test using an independent randomly derived data set indicate that our predictive function performs at least as well as other previous models when tested against an independent data set. However, an intensive evaluation of our database convinced us that the model could be refined to produce even higher levels of accuracy.

Refining the Predictive Model

There are several methods of refining a site prediction model: revising or adding new variables to the analysis, adding or deleting individual cases and repartitioning the data set into different groups. The first approach, incorporating new variables that might add further discriminatory ability to the derived functions, was used by LaPoint et al. (1981) at Douglas Creek. By adding five additional topographic and hydrographic variables to their original set of five variables, LaPoint et al. apparently increased the discriminatory ability of the derived function to segregate site and nonsite locations.

The second alternative to refining a model involves adding additional cases or deleting outliers from the training set (Mike Garratt, personal communication). Outliers inordinately increase the group variance and decrease the overall strength of the function. An evaluation of the distribution of the discriminant function scores showed that there were several outliers in our data set for the first 5% sample.

Seven of the 29 nonsite quadrats in the training set were incorrectly classified as quadrats with sites. Three of these seven had more than an 80% probability of belonging to the site group. Information from the quadrat summary forms showed that these three quadrats, two in Circle Cliffs and one in the San Rafael Swell, were environmentally similar to many other quadrats that did have sites. Since these quadrats appeared to represent quadrats with optimal site locations that were simply not used by prehistoric people, their inclusion in the training set decreased the predictive ability of the model. These three quadrats were excluded from further analysis and the refinement of the model in order to provide a greater degree of statistical separation between the quadrats with sites and the quadrats without sites.

Obviously, we cannot eliminate any quadrat with a site no matter how distant it is from the group centroid or how similar it is to the quadrats without sites. In reality, such a quadrat represents the extreme end of the distribution of occupied site locations, and as such, it must be included in the analysis. Therefore, while it is possible to decrease the variance in the group without sites by excluding cases from analysis, the same cannot be done for the group of quadrats with sites.

As noted above, another way to refine the model would be to increase the size of the training set. An increase in the sample size would decrease the variance in both groups of quadrats. If statistical differences between the groups actually exist, the addition of more cases would help overcome random variation due to a small sample size.

Our first training set consisted of 49 quadrats or 50% of the total sample, the remaining 50% was used to test the initial function. For the second stage of model development, we added the next 5 quadrats from Circle Cliffs and 14 quadrats from the San Rafael Swell to the 49 quadrats used in the initial analysis. This increased the size of our training set to 65 quadrats and decreased our test data set to 30 quadrats. Thus, approximately 68% of the data set was used to develop a second model which was tested by the remaining 32% of the quadrats.

By using the larger training set and excluding the three outliers (quadrats without sites), we refined our first predictive model by deriving another discriminant function and conducting a second validation test. The means and univariate F-ratios for each variable are presented in Table 48. While only one variable, QUADRAT COVER, had a significant univariate F-ratio in the first analysis, the exclusion of three cases and the increase in sample size caused three variables, QUADRAT COVER, ELEVATION and DISTANCE TO WOODED AREA, to be significant at the .05 level.

The results of this second discriminant analysis are presented in Table 49. The function derived for this test included all four previous discriminating variables plus two additional ones, ELEVATION and DISTANCE TO RIVER. Thus, in addition to distinguishing the same differences identified in the first analysis, the second analysis indicates that quadrats with sites are found at higher elevations while quadrats without sites are found farther away from a major river.

This second function is clearly superior to the one derived in the first model. The canonical correlation is .60 demonstrating that the function explains more than 36% of the variation in the data set compared with the 20% from the first model. Additionally, the distance between the group centroids increased (Table 50), and the pairwise F-ratio, 5.58, now represents a probability of greater than .0001.

Because of the increased discriminatory ability of the function, it is not surprising that the correct rate of self-classification for the training set also increased. This function was able to correctly classify 26 (72%) of the 36 quadrats without sites and 23 (79%) of the 29 quadrats with sites, for an overall 75% correct rate of classification.

Validation Test of the Second Function

The classification function derived from the second analysis was tested with the remaining 30 quadrats in the validation set. An overall correct classification rate of 70% was obtained with 75% of the quadrats with sites correctly predicted (12 of 16 quadrats) and 64% (9 of 14 quadrats) of the quadrats without sites correctly predicted. Thus, this second function produced a 7% higher correct rate of classification on the independent data than the first function.

This rate of correct classification is extremely good for a test data set. The 70% rate exceeds the 63% obtained by Kvamme (1983c) in the Grand Junction area and the 58% obtained by LaPoint et al. (1981) at Douglas Creek. Only Kvamme's (1980) classification results from the Glenwood Springs project have a higher classification rate (80%). It should be noted, however, that Kvamme did not apply his classification function to a random set of points to predict site presence or absence, rather a series of predefined locations with and without sites were used as the test data.

Development of the Final Model

Because we used only 65 of the quadrats to derive the second function, we expected that the predictive accuracy of the final refined model would be even greater if the total data set was included in the analysis. Of course, there would be no remaining quadrats with which to test the derived functions. Our results, however, demonstrate that as the discriminatory ability of

Table 48. Group means and univariate F-ratio for variables in the second training data set based on 65 quadrats.

Variable	Quadrats without Sites	Quadrats with Sites	All Quadrats	Univariate F-ratio
RELIEF	118.86	88.86	105.48	2.15
ELEVATION	1810.19	1935.76	1866.22	8.79
DISTANCE TO RIVER	14.52	15.26	14.85	.11
DISTANCE TO WATER	5.03	4.19	4.66	.82
QUADRAT COVER	15.08	48.79	30.12	16.46
DISTANCE TO WOODED AREA	.87	.38	.65	7.86
DRAINAGES	.61	.76	.68	.74
ASPECT-SIN	.07	-.11	-.01	1.00
ASPECT-COS	-.15	-.25	-.19	.31
Sample size	36	29	65	

Degrees of freedom for univariate F-ratio: 1, 63

Table 49. Standardized coefficients, eigenvalue, canonical correlation and pairwise F-ratio for the discriminant functions based on a training set of 65 quadrats.

Variable	Coefficient
RELIEF	.2393
ELEVATION	-.5245
DISTANCE TO RIVER	.4009
DISTANCE TO WATER	.3684
QUADRAT COVER	-.7126
DRAINAGES	-.2657
Eigenvalue	.577
Canonical correlation	.605

Pairwise F-ratio for 6 and 58 degrees of freedom = 5.58

Table 50. Group centroid values for each group for first and second discriminant analysis.

	Centroids of Groups	
Group	Function (First Analysis)	Function (Second Analysis)
Quadrats without sites	.375	.539
Quadrats with sites	-.544	-.669
Sample size	49	65

the function is sharpened, the rate of correct classification increases for both the training set and the test data set.

A review of the results of our two discriminant analyses coupled with information recorded during the field inventory suggested some significant variation in quadrats with sites was being overlooked by using a binary site presence/absence approach. The review indicated that quadrats with only a single site were qualitatively different than quadrats with two or more sites. We believed that the predictive model could be further refined by changing the number of groups in the analysis, the final method of model refinement, as noted above.

Our final model was developed using all 95 quadrats as the training set, but instead of a binary site presence/absence model, we partitioned the quadrats into three groups, those without sites, those with only one site and those with two or more sites. The same stepwise procedure was implemented with the same nine variables. The group means and univariate F-ratios are presented in Table 51. Surprisingly, six of the nine variables have a univariate F-ratio that is significant at the .05 level, indicating that these three groups of quadrats are statistically different across these variables.

Because three groups are entered into the analysis, two discriminant functions were derived. Table 52 presents the data on both of these functions. The final functions utilized the same six variables that were included in the function produced in our second discriminant analysis. It is instructive to interpret each function separately.

The first function has a canonical correlation of .64, explaining about 40% of the variation of the groups along this dimension. Because this is the first function, it is the most important function, with about 84% of the total discriminating power.

The centroids of the groups (Table 53) lie along this function so that the group of quadrats without sites is at the positive end, the group of quadrats with two or more sites is at the negative end and the group of quadrats with only one site is between them. Along this dimension then, quadrats with only one site share similarities with the other two groups.

Table 51. Group means and univariate F-ratio for variables in the final model based on 95 quadrats.

Variable	Quadrats without Sites	Quadrats with One Site	Quadrats with Two or More Sites	All Quadrats	Univariate F-ratio
RELIEF	116.9600	119.9375	72.4828	103.8842	3.4380
ELEVATION	1813.7800	1794.3750	1972.5172	1858.9684	10.3152
DISTANCE TO RIVER	13.5440	9.8312	16.9138	13.9474	3.8195
DISTANCE TO WATER	4.8220	3.9813	4.7379	4.6547	0.3313
QUADRAT COVER	17.5400	26.3125	63.3448	33.0000	19.8204
DISTANCE TO WOODED AREA	0.8000	0.5188	0.1966	0.5684	7.5202
DRAINAGES	0.5800	1.1250	0.7586	0.7263	4.0644
ASPECT-SIN	0.0780	0.0919	-0.0419	0.0437	0.3207
ASPECT-COS	-0.0536	-0.0273	-0.2417	-0.1066	0.7327
Sample size	50	16	29	95	

Degrees of freedom for univariate F-ratio: 2, 92

Table 52. Standardized discriminant function coefficients, eigenvalue, canonical correlation and group centroid values for final model.

	Discriminant Function Coefficient	
Variable	Function 1	Function 2
RELIEF	0.26208	-0.20767
ELEVATION	-0.48111	-0.20259
DISTANCE TO RIVER	0.14238	0.75869
DISTANCE TO WATER	0.29008	-0.18636
QUADRAT COVER	-0.69738	-0.07555
DRAINAGES	-0.19204	-0.81075
Eigenvalue	.679	.131
Canonical correlation	.636	.341

Table 53. Group centroid values for each group for both functions in the final discriminant analysis.

	Centroids of Groups	
Group	Function 1	Function 2
Quadrats without sites	0.50203	0.17625
Quadrats with one site	0.12036	-0.75055
Quadrats with two or more sites	-0.93198	0.11022

The coefficients for this function can be interpreted as follows. Quadrats in the higher elevations with more pinyon-juniper woodland are more likely to contain sites, while quadrats in the lower elevations, with less pinyon-juniper and greater relief and that are farther from permanent water are more likely to have one or no sites.

The second function has a canonical correlation of .34, explaining only about 12% of the variation in the groups along this dimension. Its overall discriminating power is only 16%. However, it should be remembered that this function explains variation that is not explained by the first function. Along this dimension, quadrats with one site are at the negative end of the function while quadrats with no sites or two or more sites are at the positive end of the function.

The interpretation of the coefficients for this function is somewhat obscure, particularly because quadrats without sites and quadrats with two or more sites are more like each other, than either is like the quadrats with only one site. It seems that quadrats with drainages that are close to the river are likely to have only one site. Quadrats lying at higher elevations with fewer drainages and greater relief and that are farther from the river are more likely to have no sites or several sites.

It is not clear what dimension this second function is measuring, however, the pairwise F-ratio for between each pair of groups indicates that the differences between these groups of quadrats is statistically significant at the .05

level. With 6 and 87 degrees of freedom, the pairwise F-ratio between the quadrats with no sites and the quadrats with one site is 2.27; and between quadrats with no sites and quadrats with two or more sites, 9.79; and between quadrats with one site and quadrats with two or more sites, 4.29. Another indication of the significance of the derived functions is that between the two functions, almost 52% of the variation is explained along those two dimensions.

The self-classification rates obtained for these functions is presented in Table 54. The overall classification rate is 71%. This is an exceptionally high rate of classification since the expected rate for a three-group solution is only 33%; thus the observed classification rate is 38% greater than could be expected by chance. For a two-group solution in which the expected correct chance rate is 50%, a corresponding increase would require a correct classification rate of 88%.

While these rates represent respectable predictive power in a statistical sense, from a practical standpoint they underestimate the true predictive power of these two functions. Thirty-six percent (18) of the quadrats without sites were misclassified as members of the groups of quadrats that contained sites. These misclassifications erred conservatively in terms of cultural resource preservation, however, since these quadrats would be afforded consideration by land managers until it was determined that no sites were present.

However, the more serious misclassification, in a cultural resource preservation sense, is the grouping of quadrats with sites into the group that is not expected to have sites. This is where the present model excels. While 10 of 45 quadrats with sites were misclassified, only 3 (7%) were classified in the group without sites. The remaining seven misclassifications were in assigning quadrats with one site to the group that had two or more sites or vice versa.

From a management perspective, a quadrat with one site or several sites that is misclassified into a group identified as having at least one site is still a correct classification since presumably quadrats predicted as having sites will receive special consideration. Cast in this light, *93% or 42 of the 45 quadrats with sites* in the total sample were assigned to an appropriate group with a practical error rate of about 7%. This error rate is lower than that obtained by any previous modelling efforts in Utah.

Thus, assuming that our 10% random sample of quadrats is representative of all of the 160-acre quadrats in both the Circle Cliffs and San Rafael Swell study tracts, we can expect that application of these functions might correctly identify as many as *93%* of all quadrats with sites as being in one of the groups with sites. Since this expected correct rate is based on the self-classification rate, we can expect the error

Table 54. Classification results of the final model.

	Predicted Group Membership		
Actual Group Membership	Quadrats without Sites	Quadrats with One Site	Quadrats with Two or More Sites
Quadrats without sites	32	9	9
Quadrats with one site	2	10	4
Quadrats with two or more sites	1	3	25

67 of 95 quadrats correctly classified - 71%
42 of 45 quadrats with sites correctly classified - 93%

rate to increase slightly on an independent data set.

Application of the Final Model

Applying this predictive model is relatively straightforward, particularly if the simple classification functions are used. The researcher selects a 160-acre quadrat and measures the six variables included in the classification functions. These measurements are then multiplied by the simple classification coefficients presented in Table 55 for each of the three groups. The computed values for each group are added along with a constant and the sums for each group are compared. The quadrat is then assigned to the group whose set of coefficients produced the largest value.

We will present an extended example using Quadrat 27 in the San Rafael Swell. The maximum elevation in this quadrat is 2048 m and the minimum is 1950 m. Quadrat RELIEF is the difference between these two values, 98 m. Quadrat ELEVATION is the sum of these two values divided by 2 or 1999 m. The distance to the Muddy River measured from the center of the quadrat is 28.5 km. The distance to the nearest source of permanent water, Tan Seep, is 7.6 km. Almost 90% of the quadrat is covered by green shading on the map so QUADRAT COVER is assigned a value of 87 (87% covered, see discussion of variable above). Finally, there are two intermittent blue line drainages noted on the map, so DRAINAGE is assigned a value of 2.

These values are now multiplied against each of the simple classification coefficients shown in the table and then summed with the constant for each group. For example, the following computations would be made for the group of quadrats without sites.

Score = [(-.00441)(RELIEF)]
+ [(.13870)(ELEVATION)]
+ [(-1.54104)(DISTANCE TO RIVER)]
+ [(.53104)(DISTANCE TO WATER)]
+ [(-.16803)(QUADRAT COVER)]
+ [(7.10349)(DRAINAGES)]
+ (Constant)

= [(-.00441)(98)] + [(.133870)(1999)]
+ [(-1.54104)(28.5)] + [(.53104)(7.6)]
+ [(-.16803)(87)] + [(7.10349)(2)]
+ (-116.96283)

= (-.43218) + (267.60613)
+ (-43.91964) + (4.035904)
+ (-14.61861) + (14.20698) + (-116.96283)
= 109.9

Quadrat 27 has a score of 109.9 for the group without sites. Repeating this procedure for the other two groups results in a score of 120.9 for the function for the group with one site and 122.8 for the function for the group with two or more sites. Since the highest score is 122.8, the quadrat is assigned to the group that has two or more sites. This classification is correct, because this quadrat had three sites.

Table 55. Simple classification function coefficients for the final model.

Variable	Quadrats without Sites	Quadrats with Sites	Quadrats With Two or More Sites
RELIEF	-0.00441	-0.00379	-0.01199
ELEVATION	0.13870	0.14158	0.14517
DISTANCE TO RIVER	-1.54104	-1.64183	-1.58645
DISTANCE TO WATER	0.53104	0.53360	0.34644
QUADRAT COVER	-0.16803	-0.15422	-0.12381
DRAINAGES	7.10349	8.48196	7.84429
Constant	-116.96283	-122.52582	-129.20330

The Landsat Model

A second predictive modelling effort was concurrently conducted by the University of Utah using Landsat imagery data (remote-sensed data) to determine its utility for future research and management needs. The University of Utah Archeological Center has conducted two site location prediction models based on Landsat data, the first on a railroad line in Castle Valley in central Utah (Holmer 1982) and the second on an inventory project at China Lake, California (Elston et al. 1983). Because of its expertise in developing models based on Landsat data, the University of Utah Archeological Center, under contract to P-III Associates, developed Landsat-based predictive models for the San Rafael Swell and the Circle Cliffs study tracts. The details of the application are contained in Appendix 8. This section presents background information and discusses the results of the University's modelling effort.

Background

Remote sensing consists of monitoring and recording phenomena from a distant location. Remote-sensing data can be collected with a number of different sensing devices mounted on airborne, orbiting and/or ground-based platforms. Landsat imagery, the remotely sensed data used in this site location prediction effort, is collected by a series of sensors that are carried on Landsat satellites which orbit some 900 km above the earth's surface.

The Landsat predictive modelling effort is based on the assumption that remotely sensed data can more accurately identify clusters of environmental attributes for site location prediction efforts than other currently available methods. As such, the Landsat modelling effort takes a different approach to predictive modelling. The two most obvious differences between the Landsat approach and the discriminant analysis presented above involve the discriminating variables and the selection of the analytical groups.

The analytical variables are different because they are not map-read or map-measureable but consist of four spectral reflectance bands. These bands range from optical to infrared and can differentiate various environmental characteristics. Band 4, the green band, records information on vegetation cover, sediment content in water bodies and barren ground. Band 5, the visible red band, emphasizes soils, terrain and cultural features such as cities and roads. The infrared bands, 6 and 7, are useful for recording vegetation types and boundaries between land and water.

Also, the Landsat model does not use site presence/absence as the distinguishing characteristic to derive the groups for analysis. Rather the number of groups and group composition are based on a cluster analysis of the Landsat data. These derived groups can be thought of as quasi-environmental classes or strata. There is no predetermined number of these groups nor do the derived groups represent regions with sites and regions without sites. Rather, the modelling effort is directed at deriving environmental strata and then determining, based on the inventory, the probabilities of site occurrence within each of the quasi-environmental groups. The details of the derivation of these classes are included in Appendix 8.

There is no direct relationship between the spectral bands and the cultural and behavioral factors that influenced site location. However, if the model demonstrates a significant correlation between the identified environmental groupings and prehistoric site locations, some insights about prehistoric behavior might be gained by analyzing the results of the model.

Results of the Landsat Model

Because the goal of the Landsat modelling effort was to define quasi-environmental zones, rather than to distinguish between locations with and without sites, separate Landsat models were developed for Circle Cliffs and the San Rafael Swell.

For the Circle Cliffs study tract, a cluster analysis identified three quasi-environmental zones among the 30 quadrats. The cluster analysis for the San Rafael Swell tract identified four quasi-environmental groups. The cluster analysis results for both tracts were tested against themselves using discriminant analysis. For the quadrats in Circle Cliffs, 97% were reclassified correctly into the appropriate group. The correct rate of reclassification among the four groups in the San Rafael Swell tract was 94%. These results demonstrate that there is a high degree of statistical cohesion within the groups as well as differences between them.

Table 56 shows the distribution of quadrats with and without sites in each of the groups for each of the two sample phases in each of the two study tracts. The probabilities of the occurrence of quadrats with sites were calculated and are also presented in the table. Because of the small sample size in relation to the number of derived classes, it is not surprising that the probabilities of occurrence of quadrats with sites varies from the first sample to the second sample. Using the probabilities derived from the first 5% sample for each group, the expected frequency of quadrats with sites could be derived for the second 5% sample. These expected frequency could be evaluated using a Chi-square test. While such a test would show that the derived probabilities for site occurrence in the San Rafael Swell were significant and that those for Circle Cliffs were not, the results would have to be cautiously interpreted because of the small sample size.

Combining the results from the first and second 5% samples increases the sample size and allows for the better estimates of probabilities of the occurrence of sites. For Circle Cliffs, the first quasi-environmental class would have a probability of .63, .75 for the second class and .46 for the third class. Thus, using the Landsat model to assign all of the Circle Cliffs study tract into one of these three groups, the percent of 160-acre quadrats with at least one site in each of the groups would range from 46% to 75%. While the model can segregate environmental classes in the Circle Cliffs tract, site locations do not seem to be highly correlated with any of these environmental strata.

For the San Rafael Swell, however, the derived probabilities for quadrats with sites improves slightly. For Class 1 the probability is .38; for Class 2, 1.00; for Class 3, .36; and for Class 4, .22. Using this Landsat solution in the San Rafael tract would produce four groups, one of which would have at least one site in every quadrat (Class 2) because it has a 100%

Table 56. Distribution of quadrats and probabilities (p) for Landsat model.

	First 5% Sample			Second 5% Sample		
Environmental Class	Quadrats without Sites	Quadrats with Sites	(p)	Quadrats without Sites	Quadrats with Sites	(p)
CIRCLE CLIFFS						
Class 1	3	4	.57	1	3	.75
Class 2	0	2	1.00	2	4	.66
Class 3	4	2	.33	2	3	.60
SAN RAFAEL SWELL						
Class 1	4	6	.60	9	2	.18
Class 2	0	2	1.00	0	3	1.00
Class 3	12	3	.13	9	9	.50
Class 4	6	1	.14	1	1	.50

probability of occurrence, and another group (Class 4) in which only 22% of the quadrats would have sites. In the other two classes, 36% and 38% of the quadrats would have sites. The model for the San Rafael tract identified environmental classes that are more highly correlated with site location than the model for Circle Cliffs.

Discussion

What can be interpreted from the results of these two predictive modelling approaches? The final three-group discriminant analysis demonstrated that quadrats with only one site can be distinctly differentiated from quadrats without sites or quadrats with several sites. We do not have an explanation for this except that the single sites in these quadrats generally represent small, limited activity sites that occur in a localized, anomalous portion of the quadrat. The quadrats in which these isolated sites are found may represent areas where more specialized or limited types of activities were occurring such as hunting or plant gathering or lithic material procurement. For such sites, variables such as distance to water, percent of quadrat cover, etc., may not have been key factors in site location at all. We note, as do previous researchers, that site type is a critical factor in understanding the site selection process for prehistoric peoples.

The Landsat model identified several environmental zones with varying probabilities of having quadrats with sites. These zones do not have immediate on-the-ground interpretability, so their use in understanding variables that were critical to the prehistoric site selection process is minimal. The value of such models is that they may ultimately be further refined to more accurately evaluate both on-site and area wide natural resources that are correlated with site locations in a broad sense.

Comparisons between the two methods indicates that the final discriminant model has more general applicability because the error rate in the predicted group membership is less with the discriminant model. Additionally, the Landsat model cannot be immediately implemented by a land manager. Use of the Landsat model requires access to the computerized database and the computer programs to derive the information. The discriminant model can be used by anyone who has access to the topographic maps and a portable calculator.

Conclusion

We have presented two models for predicting site locations, the first a multivariate discriminant analysis of map-readable variables and the second, a predictive model based on Landsat data. The discriminant analysis approach was developed on the first 5% sample and tested against the second 5% sample with statistically significant, but not overly impressive results. This model was refined by excluding several cases and increasing the sample size, and then tested against a smaller data set. The results of this second analysis were an improvement over the first discriminant analysis. The final model was developed using the entire data set and a three-group discriminant analysis. This increase in the size of the training set and the partitioning of the database into three groups resulted in the final classification functions which were extremely successful in identifying quadrats with sites.

The Landsat model was developed independently for two study tracts, Circle Cliffs and the San Rafael Swell. Quasi-environmental zones were identified and probabilities of occurrence of quadrats with sites were predicted for each zone for future use. The data indicated that the probabilities from the San Rafael Swell would have more utility for management purposes.

The results of the final discriminant model were compared to the Landsat model. The discriminant model was recommended because of its better rates of classification and ease of use. The three-group discriminant quadrat model appears to the most efficacious model for the San Rafael and Circle Cliff study tracts. Use of this model for management purposes will result in a low error rate of classification for quadrats with sites. The application of this model should greatly improve management efforts to avoid cultural resources during the planning process and will shed important light on research questions concerning the distribution of highly clustered sites in environmentally marginal areas.

Chapter 9

CONCLUSION

During the last half of 1983, P-III Associates, Inc., conducted a Class II cultural resource inventory and predictive modelling study of three tar sands study tracts located in central and southern Utah. The work was conducted for the Bureau of Land Management, Richfield District Office, and was necessary to fulfill various laws and regulations requiring the identification, consideration and protection of cultural resources.

The objectives of the project were to (1) provide cultural resource data for an Environmental Impact Statement on tar sands development and (2) develop a predictive model of site location. The cultural resource data were to be obtained through a file search and literature review, as well as an intensive pedestrian inventory of two 5% samples of the project area. Survey units were to be cadastrally aligned 160-acre quadrats. The model was to be developed using the first 5% sample, tested with the second 5% sample and be suitable for management purposes. In addition to fulfilling these management goals, we also hoped to enhance the scientific understanding of human occupation in the project area through examination and interpretation of the collected data, and through limited comparison with data sets from nearby areas.

The project area consisted of three geographically separate tracts of land located in Circle Cliffs, east of Boulder, Utah; the San Rafael Swell, west of Green River and east of Emery, Utah; and White Canyon, north of Fry Canyon, Utah. There are about 50,300 acres in the Circle Cliffs study tract, 111,200 acres in the San Rafael Swell study tract and 10,500 acres in White Canyon study tract. Together these tracts comprise approximately 172,000 acres.

The inventory resulted in the discovery and documentation of 155 prehistoric and historic sites, and 274 isolated finds within the survey quadrats. Another 11 sites and 10 isolated finds were recorded outside the survey quadrats but within the boundaries of the project area. These 166 sites unequivocally reflect 5 cultural groups: Archaic, Fremont, Anasazi, Numic and Euroamerican, and span the era between the Early Archaic and the recent past. Unfortunately the bulk of the recorded sites could not be associated with any particular time period or cultural group.

Most of the sites are field camps and base camps that were used for short-term camping and/or temporary residence. A smaller number were used for specialized activities such as stone procurement, tool manufacture, tool maintenance or food storage. A still smaller group of sites were used for year-round or long-term occupation; they evince a wide range of domestic undertakings and some evidence of ceremonial behavior.

Two models of site location were developed with data derived from Circle Cliffs and the San Rafael Swell. The first model utilized discriminant analysis to segregate 160-acre quadrats with sites from those without sites. After several revisions, the final model was able to correctly classify more than 90% of the quadrats with sites. Using the same data set, the University of Utah Archeological Center developed separate predictive models for the Circle Cliffs and San Rafael Swell study tracts using remotely sensed Landsat data. These models are not as practical as the discriminant model for managing cultural resources. However, Landsat modelling may hold some promise for delineating environmental strata that may be useful in future cultural resource investigations.

Project Results

Prior to the survey, the project area was poorly known archeologically—less than half dozen sites had been previously recorded in the 172,000 acres composing the three study tracts. The Tar Sands Project has refined our knowledge of prehistoric occupation in Circle Cliffs, the San Rafael Swell and White Canyon, by providing information on the cultural affiliation and chronological placement of the people who lived there, site type and function, prehistoric settlement patterns, site density and distribution relative to environmental characteristics, lithic technology and procurement, and extraregional relationships and influences. The following paragraphs summarize some of the data that was gathered by the project as they relate to these research topics.

All of the major periods and cultural groups discussed in Chapter 3 were identified in the project area with the possible exception of Paleoindian: some would consider the Lake Mohave point recovered from a site in the San Rafael Swell to be Paleoindian, whereas others might regard it as transitional Paleoindian/Early Archaic. Lake Mohave points were recovered from pre-9000 B.P. deposits at Danger Cave (Jennings 1957) and Early Archaic (circa 7850 B.P.) deposits at Hogup Cave (Aikens 1970). The majority of sites identifiable to affiliation can be attributed to Archaic peoples based on cross-dating of the projectile points, with the Early, Middle and Late periods all represented. Only limited evidence of Fremont occupation was found in the San Rafael Swell, though there was more indication of Anasazi in White Canyon. Several Numic sites were found in Circle Cliffs and the San Rafael Swell. The few historic sites noted during the inventory were mainly associated with turn-of-the-century ranching and mining activities.

The results of the survey do not appreciably alter the culture history of the region as described in Chapter 3, but do confirm the abundance of Archaic sites suspected in the area—but not yet reported—by many researchers. Unfortunately, the survey did little to resolve issues such as the Virgin Anasazi/Kayenta Anasazi/Fremont problem in Circle Cliffs, the question of Basketmaker II presence in Circle Cliffs and the San Rafael Swell, the affiliation of Anasazi groups in the White Canyon area and the distinguishing attributes of San Rafael Fremont nonhabitation sites. These issues will have to await future investigations involving excavation and in-depth analyses.

With the exception of rock art, the range of site types observed in all three study tracts is similar to that observed by previous researchers working in adjacent areas. Rock art sites are common in the vicinity of all three study tracts, but not present in the survey quadrats. The lack of rock art sites clearly reflects the bias of the sampling universe toward the exposure of lower Triassic formations: Moenkopi, Shinarump and Chinle. None of these formations produce sandstone faces suitable for making rock art.

With the exception of White Canyon, the project area appears to have been used on a seasonal basis—field camps and base camps were the most common types of sites, with fewer limited activity loci. Habitation locales representing year-round occupation, or at least occupation for a substantial part of the year, were only common in White Canyon. The frequencies of the various site types differ from those reported by other researchers working in adjacent areas; most likely, these differences are due to environmental factors and the environmental bias of the sampling universe noted above.

Sites in all three survey quadrats are highly aggregated. All of the sites in Circle Cliffs were found in only 60% of the quadrats, whereas approximately 40% of the quadrats in both the San Rafael Swell and White Canyon contained all of the sites. This highly clustered distribution is a reflection of the moderate environmental diversity in Circle Cliffs and the great diversity in the San Rafael Swell and White Canyon study tracts. How much, if any of this pattern can be attributed to the biased nature of the sampling universe noted above is not known.

As observed by other researchers working in nearby areas, most the sites occur in the pinyon-juniper woodland with fewer sites lying in predominantly desert shrub, sagebrush or grassland communities. Slightly more than half of all sites were found in tableland/mesa settings, whereas roughly 30% were situated in open rolling valleys. Archaic sites were differentially distributed by elevation and distance to water, with Late Archaic sites occurring an average of 50 to 100 m higher than other sites and Middle Archaic sites lying up to almost twice as far from permanent water sources as Fremont or other Archaic sites. This variation suggests differing adaptational responses to changing environmental conditions during the Archaic period.

In-field analyses of the chipped stone tool assemblages indicated that most of the stone was procured at sources away from the sites, and partially reduced before it was transported to the sites recorded by the survey. On-site reduction emphasized secondary thinning of what were probably already blanks or preforms. The exceptions are a few gravel terrace sites in the northern end of the San Rafael Swell where on-site activities were primarily limited to stone testing and early stages of cobble reduction.

Raw materials observed on sites in Circle Cliffs and the San Rafael Swell were generally of high quality, with no appreciable differences in material types present in the tool and debitage assemblages. The sources of these materials were not located during the survey, but most materials are probably from the Chinle Formation, and possibly the Kaibab Limestone, Shinarump Conglomerate and Mancos Shale (Tununk Member). A lower quality, apparently more locally available, blue-gray chert predominated the debitage assemblage in White Canyon. A different material of a consistently higher quality was used for formal chipped stone tools. This material was apparently imported, possibly from the gravel terraces along the Colorado River.

Statistical analyses of the projectile point assemblage allowed the tentative definition of two new point types, San Rafael Stemmed and Sinbad Side-notched. The former has a large, slender, triangular blade with straight edges, wide corner notches that cause pronounced shoulders or tangs, and a long and wide, slightly expanding stem. San Rafael Stemmed points were found with Pinto, Elko and Gypsum points, and may date to the Archaic period. They occur in both Circle Cliffs and the San Rafael Swell.

The somewhat more tentative Sinbad Side-notched is a small, short, lanceolate point with convex blade margins, very shallow side notches and a straight to slightly concave base. An outstanding feature of this point type is its thickness relative to its overall size. Though its small size is within the range of arrow points generally dated to the Late Prehistoric period, Sinbad Side-notched points were found with several Early and Middle Archaic point styles and may be contemporaneous. Other arrow point-size projectile points have been found in terminal Paleoindian/Early Archaic contexts at Danger Cave (Aikens 1970; Jennings 1957). These points were also distinguished by their unusual thickness.

Evidence of extraregional relationships was limited in the three study tracts, but of the type and directions expected for the area. The obsidian flakes and biface observed in Circle Cliffs are clearly imports as obsidian does not occur locally. Unfortunately, the source or sources are not presently known. The closest quarries are in the Mineral Mountains of southwestern Utah. Other evidence of extraregional relationships was limited to a piece of Kayenta Anasazi pottery in the San Rafael Swell, Parowan Fremont pottery on sites within the geographical confines of the San Rafael Fremont (cf. Marwitt 1970) and Hopi pottery in White Canyon. The presence of Great Basin (e.g., Lake Mohave, Rose Spring), Rocky Mountain (e.g., Mt. Albion Corner-notched) and Plains (e.g., Oxbow, Hawken Side-notched) projectile point types in the project area may indicate both influence and extraregional trade.

A total of 54 sites was recorded in the 30 survey quadrats in Circle Cliffs. Based on these data, we project a total of 530 ± 208 sites in the overall study tract. The preponderance of sites identifiable to affiliation are Archaic, with one Numic and five Euroamerican sites also recorded. The discovery of a pithouse radiocarbon dated to A.D. 250 and numerous Elko points raises the possibility of Basketmaker II occupation in the Circle Cliffs study tract, though without further investigations, an Archaic or pre-Fremont origin cannot be discounted for the pithouse. The absence of Anasazi sites in the study tract is probably related the ubiquity of poor residual soil and the general lack of arable land. Anasazi sites *are* present in immediately adjacent areas where more hospitable conditions predominate. Of course it is also possible that some of the 43 undiagnostic lithic scatters are of Anasazi origin. If the Anasazi used the Circle Cliffs study tract, it was for ephemeral activities such as hunting, gathering and resource procurement rather than long-term habitation.

Except for the historic period, all use of the study tract was on a relatively short-term, probably seasonal basis as indicated by the lack of habitation sites and the preponderance of field camps. The study tract contains numerous resources that would have been attractive to hunting and gathering groups. The presence of midden deposits on a Late Archaic base camp and on three other sites of unknown affiliation offers excellent potential for generating data on subsistence patterns and seasonal usage of the study tract.

Sites in Circle Cliffs generally occur on ridges overlooking small drainages, on terraces above small intermittent tributaries, on mesa tops commanding sweeping views of the valley and in open valleys adjacent to the major intermittent drainages. Pinyon-juniper settings were clearly preferred and most sites occur on residual soil—most likely because it is the predominant and virtually ubiquitous substrate in the study tract.

A total of 81 sites was recorded in survey quadrats in the San Rafael Swell, with an estimated 800 ± 344 sites in the overall study tract. Among the sites identifiable to affiliation, Archaic comprises 60%, and Fremont only a meager 20%. Several Numic and Euroamerican sites were also recorded, and as noted, the Lake Mohave point could be taken as evidence of Paleoindian or Paleoindian/Early Archaic presence. The presence of numerous Elko points again raises the possibility of occupation during the early part of the Late Prehistoric period, occupation which some might consider Basketmaker II. We prefer to avoid this term because it connotes early Anasazi rather than Fremont origins, a link that has yet to be demonstrated in this area.

The low frequency of Fremont sites in the San Rafael Swell may be related to (1) the marginality of the study tract relative to areas normally inhabited by this semi-sedentary group and (2) the Fremont using the area for activities that left few clues about their affiliation. Some of the 57 undiagnostic sites are surely the result of Fremont occupation. It is clear that all prehistoric and protohistoric use of the area, including the Fremont, was both sporadic and seasonal. Field and base camps predominate with not a single habitation site identified. While such a pattern is expected for the Archaic era, it differs from the traditional view of the Fremont as inhabiting large sites along water courses near arable land on a relatively long-term, year-round basis (Jennings 1978).

In the northern end of the San Rafael Swell, sites are primarily concentrated on flat benches along major drainages and in alcoves and overhangs inside the drainage rims. Mesa tops were preferred in the central portion of the study tract and seeps were a common site location farther south. Sites were found on a variety of land forms—valley, tableland/mesa, canyon—primarily on eolian or residual accumulations. Pinyon-juniper is the most common vegetational setting.

Twenty sites were recorded in the White Canyon study tract. Most are of Anasazi affiliation, though two Archaic sites dating to the Middle Archaic period were also noted. Analysis of the pottery and structural features suggests that most of the Anasazi sites date to the Pueblo II-III era, though some Pueblo IV materials were noted. As Lucius notes, the presence of Pueblo IV pottery does not necessarily indicate Hopi presence or occupation; it could be the result of other protohistoric groups discarding trade wares as they passed through the area. Though often included in the Mesa Verde region, the pottery from White Canyon was predominantly of Kayenta Anasazi manufacture. It is not known whether its presence reflects trade or actual Kayenta Anasazi presence.

Sites in White Canyon occur on both the tableland flats and high mesas in the pinyon-juniper woodland. The former are situated in dune or eolian settings overlooking intermittent drainages, whereas the latter lie on small ledges around the heads of drainages.

In closing this section, we wish to emphasize that the conclusions and patterns of culture identified by the project are only intended to refer to the actual study tracts, not to the region in general. The environmental setting of the study tracts is not necessarily representative of each region in general because the boundaries of the tracts were drawn to maximize the exposure of tar sands-bearing Lower Triassic formations. Because of this, the tracts included an inordinate proportion of the area's most rugged, barren, steep and inhospitable terrain. Quadrats in these areas contained only a few sites, generally representing ephemeral use. Along the boundaries of the study tracts where survey quadrats extended onto the more hospitable terrain of the adjacent flats, higher site densities were more common as was evidence of more intensive prehistoric use. We suspect that work in adjacent areas outside the tar sands tracts will produce many similar results, but also some interesting differences.

Modelling Results

A multivariate site location model was developed for the combined data set from Circle Cliffs and the San Rafael Swell. This model used a stepwise discriminant analysis to predict site presence or absence in each 160-acre quadrat. The preliminary site location model was developed using the first 5% sample. When tested with data from the second 5% sample, it was only able to correctly classify 63% of the quadrats. Detailed scrutiny of the model indicated that greater predictive accuracy could be obtained by making several refinements.

The model was refined by increasing the size of the training set and deleting several outlying cases. Testing of this refined model with an independent sample showed an improvement of 7%; it was able to correctly segregate quadrats with sites from those without sites 70% of the time.

The final model was developed using all 95 quadrats in Circle Cliffs and the San Rafael Swell and a three-group solution: quadrats with no sites, quadrats with one site and quadrats with two or more sites. Although this model has an overall self classification rate of 71%, it is a great improvement over the previous models when viewed from a management perspective. Only 7% of the quadrats with sites were incorrectly classified as containing no sites. Other classification errors were assigning quadrats with one site to the group that has two or more sites, or vice versa, and classifying quadrats with no sites in one of the two site groups. These errors are not serious from a management perspective because all quadrats classified as having sites would be afforded consideration until it was determined that no sites were present. Viewed from this perspective, the model has a practical error rate of less than 10%.

Separate models were developed for Circle Cliffs and the San Rafael Swell using Landsat imagery data. Cluster analysis was used to identify quasi-environmental strata in each study tract. Then the probability of quadrats containing sites was computed for each stratum. The probability of a quadrat containing one or more sites ranged from .46 to .75 for the three strata in Circle Cliffs and from .22 to 1.00 in the four strata in the San Rafael Swell. These models are less useful for management purposes than the discriminant model because quadrats in all of the strata are predicted to contain sites at least 22% of the time.

Recommendations

All of the sites that are considered potentially eligible to the National Register of Historic Places should be preserved – tar sands development near these sites should be avoided if possible. If preservation is not possible, detailed research designs and mitigation programs should be developed and implemented to recover the significant data at all potentially eligible sites that will be damaged or destroyed.

If tar sands development becomes a reality, affected areas that have not already been surveyed (in the 10% sample) will need to be inventoried to identify all significant resources. If the development is small scale, or will only disturb limited areas, further research efforts should be directed at the potentially eligible sites that will be damaged by development. However, if large tracts of the region will be developed—resulting in the loss of large numbers of eligible and noneligible sites—some form of data recovery should be implemented on a sample of all site types that will be destroyed.

We also recommend that the BLM seriously consider *indirect* impacts, not only on the resources within each tar sands area, but also on the sites that may lie around the periphery of each study tract. Because the BLM drew the boundaries of the study tracts to maximize the exposure of tar sands-bearing strata (i.e., the Moenkopi and Chinle formations), much of the area's most desirable flat lands were excluded from the samples. All three tracts, but the San Rafael Swell and White Canyon study tracts in particular, contain large areas of flat land just outside of the areas projected for tar sands development. We recommend that the BLM consider these potentially high-site density areas, and the possibility that they contain a high percentage of potentially eligible sites.

The recovery of large numbers of diagnostic implements, including a complete fire drill, attest to the relatively pristine nature of the cultural resources in the three study tracts. Some sites, however, especially those near roads or in highly visible alcoves, have been looted and disturbed. Such vandalism will increase with the influx of people associated with tar sands development. The BLM should take steps to alleviate indirect harm to cultural resources due to increased visitation in the area.

Finally, the BLM should be aware that the cultural resource base will continue to diminish, regardless of tar sands development. We recommend close monitoring of all sites identified as potentially eligible to the National Register. If it appears that these sites may be subject to vandalism, increased erosion, or damage by development, the BLM should develop site protection plans or implement data recovery programs to preserve the significant information before it is lost or destroyed. All three study tracts have significant cultural resources that should be preserved and protected for future generations.

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APPENDIX 1

SUPPLEMENTARY TABLES

Table 57. List of sites in Circle Cliffs, and their type, chronological placement and cultural affiliation.

Site Number	Descriptive Site Type	Chronological Placement	Cultural Affiliation
42GA2513	Historic site	Historic	Euroamerican
42GA2514	Lithic scatter	Late Archaic	Archaic
42GA2515	Lithic scatter	Prehistoric	Unknown
42GA2516	Lithic scatter	Prehistoric	Unknown
42GA2517	Lithic scatter with features	Prehistoric	Unknown
42GA2518	Lithic scatter with features	Late Archaic	Archaic
42GA2519	Lithic scatter	Prehistoric	Unknown
42GA2520	Lithic scatter	Prehistoric	Unknown
42GA2523	Lithic scatter	Prehistoric	Unknown
42GA2524	Lithic scatter	Prehistoric	Unknown
42GA2525	Lithic scatter	Middle Archaic	Archaic
42GA2526	Lithic scatter	Prehistoric	Unknown
42GA2527	Lithic scatter	Prehistoric	Unknown
42GA2528	Lithic scatter	Prehistoric	Unknown
	Historic site	Historic	Euroamerican
42GA2530	Lithic scatter	Middle Archaic	Archaic
42GA2531	Lithic scatter	Prehistoric	Unknown
42GA2532	Lithic scatter	Prehistoric	Unknown
42GA2533	Lithic scatter	Prehistoric	Unknown
42GA2534	Lithic scatter	Prehistoric	Unknown
42GA2535	Lithic scatter	Prehistoric	Unknown
42GA2536	Lithic scatter	Middle Archaic	Archaic
42GA2537	Lithic scatter	Prehistoric	Unknown
42GA2538	Lithic scatter	Prehistoric	Unknown
42GA2539	Lithic scatter	Protohistoric	Numic
42GA2540	Lithic scatter	Prehistoric	Unknown
	Historic site	Historic	Euroamerican
42GA2541	Lithic scatter	Prehistoric	Unknown
42GA2542	Lithic scatter	Prehistoric	Unknown
	Historic site	Historic	Euroamerican
42GA2543	Lithic scatter	Prehistoric	Unknown
42GA2544	Lithic scatter	Prehistoric	Unknown
42GA2545	Lithic scatter	Middle Archaic	Archaic
42GA2547	Lithic scatter	Prehistoric	Unknown
42GA2548	Lithic scatter	Prehistoric	Unknown
42GA2549	Lithic scatter	Prehistoric	Unknown
42GA2550	Lithic scatter	Prehistoric	Unknown
42GA2551	Lithic scatter	Prehistoric	Unknown
42GA2552	Lithic scatter with features	Prehistoric	Unknown
42GA2553	Lithic scatter	Prehistoric	Unknown
42GA2555	Lithic scatter with features	Prehistoric	Unknown

Table 57. Continued

Site Number	Descriptive Site Type	Chronological Placement	Cultural Affiliation
42GA2556	Lithic scatter	Prehistoric	Unknown
42GA2558	Lithic scatter	Middle Archaic	Archaic
42GA2559	Lithic scatter with features	Prehistoric	Unknown
42GA2560	Lithic scatter	Prehistoric	Unknown
42GA2561	Lithic scatter	Prehistoric	Unknown
42GA2562	Lithic scatter	Prehistoric	Unknown
42GA2563	Lithic scatter with features	Prehistoric	Unknown
42GA2564	Lithic scatter with features	Prehistoric	Unknown
42GA2565	Lithic scatter	Prehistoric	Unknown
42GA2566	Lithic scatter	Prehistoric	Unknown
42GA2567	Lithic scatter	Prehistoric	Unknown
42GA2570	Pithouse	Prehistoric	Unknown
42GA2571	Lithic scatter	Late Archaic	Archaic
42GA2572	Rockshelter	Prehistoric	Unknown
	Historic site	Historic	Euroamerican
42GA2573	Lithic scatter	Prehistoric	Unknown
42GA2574	Lithic scatter with features	Late Archaic	Archaic

Table 58. List of sites in the San Rafael Swell, and their type, chronological placement and cultural affiliation.

Site Number	Descriptive Site Type	Chronological Placement	Cultural Affiliation
42EM1674	Lithic scatter	Prehistoric	Unknown
42EM1675	Lithic scatter	Prehistoric	Unknown
42EM1676	Lithic scatter	Middle Archaic	Archaic
42EM1677	Buried site	Prehistoric	Unknown
42EM1678	Lithic scatter	Late Archaic	Archaic
42EM1679	Buried site	Early Archaic	Archaic
42EM1680	Buried site	Prehistoric	Unknown
42EM1681	Buried site Historic site	Prehistoric Historic	Unknown Euroamerican
42EM1682	Lithic scatter	Prehistoric	Unknown
42EM1683	Lithic source area	Prehistoric	Unknown
42EM1684	Lithic scatter	Prehistoric	Unknown
42EM1685	Lithic scatter	Prehistoric	Unknown
42EM1686	Lithic scatter	Middle Archaic	Archaic
42EM1687	Lithic scatter	Prehistoric	Unknown
42EM1688	Lithic scatter	Late Archaic	Archaic
42EM1689	Lithic scatter	Prehistoric	Unknown
42EM1690	Lithic scatter	Prehistoric	Unknown
42EM1691	Lithic scatter	Prehistoric	Unknown
42EM1692	Lithic scatter	Prehistoric	Unknown
42EM1693	Lithic scatter	Prehistoric	Unknown
42EM1694	Lithic scatter	Middle Archaic	Archaic
42EM1695	Lithic scatter	Prehistoric	Unknown
42EM1696	Sherd and lithic scatter with features	Middle Archaic Fremont	Archaic Fremont
42EM1697	Lithic source area	Prehistoric	Unknown
42EM1698	Lithic scatter with features	Late Archaic	Archaic
42EM1699	Sherd and lithic scatter with features	Fremont	Fremont
42EM1700	Lithic source area	Prehistoric	Unknown
42EM1704	Lithic scatter Historic site	Prehistoric Historic	Unknown Euroamerican
42EM1705	Lithic scatter with feature	Early Archaic	Archaic
42EM1706	Lithic scatter	Prehistoric	Unknown
42EM1707	Lithic scatter	Prehistoric	Unknown
42EM1708	Lithic scatter	Prehistoric	Unknown
42EM1709	Lithic scatter with feature	Prehistoric	Unknown
42EM1710	Lithic scatter with features	Early Archaic	Archaic

Table 58. Continued.

Site Number	Descriptive Site Type	Chronological Placement	Cultural Affiliation
42EM1711	Lithic scatter with features	Prehistoric	Unknown
42EM1712	Lithic scatter Historic site	Prehistoric Historic	Unknown Euroamerican
42EM1713	Lithic scatter	Prehistoric	Unknown
42EM1714	Lithic scatter	Early Archaic	Archaic
42EM1715	Rockshelter	Prehistoric	Unknown
42EM1716	Rockshelter	Fremont	Fremont
42EM1717	Rockshelter	Prehistoric	Unknown
42EM1718	Rockshelter	Prehistoric	Unknown
42EM1719	Lithic scatter with feature	Prehistoric	Unknown
42EM1720	Rockshelter	Prehistoric	Unknown
42EM1721	Lithic scatter	Prehistoric	Unknown
42EM1722	Rockshelter	Prehistoric	Unknown
42EM1723	Lithic scatter	Prehistoric	Unknown
42EM1724	Lithic scatter	Prehistoric	Unknown
42EM1725	Lithic scatter with feature	Prehistoric	Unknown
42EM1726	Lithic scatter	Late Archaic	Archaic
42EM1727	Sherd and lithic scatter	Fremont	Fremont
42EM1728	Lithic scatter	Prehistoric	Unknown
42EM1729	Lithic scatter	Prehistoric	Unknown
42EM1730	Lithic scatter	Late Archaic	Archaic
42EM1731	Lithic scatter	Prehistoric	Unknown
42EM1732	Lithic scatter with features	Prehistoric	Unknown
42EM1733	Lithic scatter	Prehistoric	Unknown
42EM1734	Lithic scatter	Prehistoric	Unknown
42EM1735	Lithic scatter	Prehistoric	Unknown
42EM1736	Lithic scatter with features	Prehistoric	Unknown
42EM1737	Lithic scatter	Prehistoric	Unknown
42EM1738	Historic site	Historic	Euroamerican
42EM1739	Lithic scatter	Prehistoric	Unknown
42EM1740	Lithic scatter	Prehistoric	Unknown
42EM1741	Lithic scatter	Prehistoric	Unknown
42EM1742	Lithic scatter	Prehistoric	Unknown
42EM1743	Lithic scatter	Prehistoric	Unknown
42EM1744	Lithic scatter	Prehistoric	Unknown
42EM1745	Lithic scatter	Late Archaic Protohistoric	Archaic Numic
42EM1746	Lithic scatter	Early Archaic Protohistoric	Archaic Numic

Table 58. Continued.

Site Number	Descriptive Site Type	Chronological Placement	Cultural Affiliation
42EM1747	Lithic scatter with features	Early Archaic	Archaic
42EM1748	Lithic scatter	Early Archaic	Archaic
42EM1749	Lithic scatter	Fremont	Fremont
42EM1750	Lithic scatter	Prehistoric	Unknown
42EM1751	Lithic scatter	Prehistoric	Unknown
42EM1752	Lithic scatter with feature	Prehistoric	Unknown
42EM1753	Sherd and lithic scatter	Fremont	Fremont
42EM1754	Lithic scatter	Prehistoric	Unknown
42EM1755	Lithic scatter	Prehistoric	Unknown
42EM1756	Rockshelter	Late Archaic	Archaic
42EM1757	Lithic scatter	Prehistoric	Unknown

Table 59. List of sites in White Canyon, and their type, chronological placement and cultural affiliation.

Site Number	Descriptive Site Type	Chronological Placement	Cultural Affiliation
42SA14404	Sherd and lithic scatter with features	Pueblo II-III	Anasazi
42SA14405	Sherd and lithic scatter with features	Pueblo II-III	Anasazi
42SA14406	Masonry architecture site	Pueblo II-III	Anasazi
42SA14407	Masonry architecture site	Pueblo II-III	Anasazi
42SA14408	Masonry architecture site	Pueblo II-III	Anasazi
42SA14409	Masonry architecture site	Pueblo II-III	Anasazi
42SA14410	Masonry architecture site	Pueblo II-III	Anasazi
42SA14411	Masonry architecture site	Pueblo II-III	Anasazi
42SA14412	Sherd and lithic scatter with features	Pueblo II-III	Anasazi
42SA14413	Sherd and lithic scatter	Pueblo II-III	Anasazi
42SA14414	Masonry architecture site	Pueblo II-III	Anasazi
42SA14415	Masonry architecture site	Pueblo II-III	Anasazi
42SA14416	Lithic scatter	Prehistoric	Unknown
42SA14417	Sherd and lithic scatter with features	Pueblo II-III	Anasazi
42SA14418	Masonry architecture site	Pueblo II-III	Anasazi
42SA14419	Sherd and lithic scatter with feature	Pueblo II-III	Anasazi
42SA14420	Lithic scatter	Prehistoric	Unknown
42SA14421	Lithic scatter with features	Prehistoric	Unknown
42SA14422	Sherd and lithic scatter	Middle Archaic Pueblo IV	Archaic Anasazi
42SA14423	Sherd and lithic scatter	Middle Archaic Pueblo II-III	Archaic Anasazi

Table 60. Frequency of features by site.

Site Number	Hearth	Burned/Fire Cracked Rock Scatter	Burned/Fire Cracked Rock Concentration	Rock Alignment	Stone Circle	Circular Stone Structure	Wickiup/Windbreak	Cist	Pithouse	Midden	Rubble Mound	Masonry Structure	Total
CIRCLE CLIFFS													
42GA2517	2												2
42GA2518	1												1
42GA2552	2												2
42GA2555	2												2
42GA2559	1												1
42GA2563		1								1			2
42GA2564										1			1
42GA2570	2								1				3
42GA2572	1	1								1			3
42GA2574										1			1
Subtotal	11	2	0	0	0	0	0	0	1	4	0	0	18
SAN RAFAEL SWELL													
42EM1696	6												6
42EM1698	1		9				2						12
42EM1699	1		1										2
42EM1705	1												1
42EM1709	1												1
42EM1710	1									1			2
42EM1711	2	1											3
42EM1715		1		3									4
42EM1716		1		2									3
42EM1717		1											1
42EM1718		1	2										3
42EM1719								1					1
42EM1720			1	2				2					5
42EM1725	1												1
42EM1732						7							7
42EM1736					1								1
42EM1747	1												1
42EM1752	1												1
42EM1756		1		2		3							6
Subtotal	16	6	13	9	1	10	2	3	0	1	0	0	61
WHITE CANYON													
42SA14404	3		1										4
42SA14405	3												3
42SA14406	1	1											2
42SA14407			1							1	1	1	4
42SA14408		1								1	1		3
42SA14409		1	1					1		1	1	1	6
42SA14410	1	1	1	2				2		1			8
42SA14411		5	1					1		2	1		10
42SA14412	1												1
42SA14414			1							1			2
42SA14415		1	1								1		3
42SA14417	1	1											2
42SA14418	3	3								1	3		10
42SA14419		1		1									2
42SA14421	1	1											2
42SA14423		1								2			3
Subtotal	14	17	7	3	0	0	0	4	0	10	8	2	65
Total	41	25	20	12	1	10	2	7	1	15	8	2	144

Table 61. Frequency of projectile points by site in Circle Cliffs.

Site Number	Lake Mohave	Pinto Series	Sinbad Side-notched	Humboldt Concave Base	Northern Side-notched	Rocker Side-notched	Hawken Side-notched	Sudden Side-notched	Mt. Albion Corner-notched	Oxbow	McKean Lanceolate	San Rafael Side-notched	Gypsum	San Rafael Stemmed	Elko Series	Rose Spring	Nawthis Side-notched	Bull Creek	Desert Side-notched	Indeterminate stemmed	Indeterminate medium, stemmed	Indeterminate small, triangular	Indeterminate leaf-shaped	Small Anasazi side-notched	Small Anasazi corner-notched	Large Anasazi corner-notched	Indeterminate	Total
42GA2514													1	1													3	5
42GA2518															1	2												3
42GA2519																											1	1
42GA2520															1													1
42GA2525		1					1						2	1	1												2	8
42GA2528																											1	1
42GA2530							1				1	1			2													5
42GA2531															1													1
42GA2532																				1								1
42GA2533															4												2	6
42GA2534																				1							1	2
42GA2535																											1	1
42GA2536									1						1												1	3
42GA2539																			1								2	3
42GA2540																						1						1
42GA2543															1													1
42GA2545								1							1												2	4
42GA2551																											1	1
42GA2552																											1	1
42GA2558								1					1															2
42GA2563															1													1
42GA2564															2													2
42GA2567																											2	2
42GA2571													1															1
42GA2574															1	1												2
Total	0	1	0	0	0	0	2	2	1	0	1	1	5	2	17	3	0	0	1	2	0	1	0	0	0	0	20	59

Table 62. Frequency of projectile points by site in the San Rafael Swell.

Site Number	Lake Mohave	Pinto Series	Sinbad Side-notched	Humboldt Concave Base	Northern Side-notched	Rocker Side-notched	Hawken Side-notched	Sudden Side-notched	Mt. Albion Corner-notched	Oxbow	McKean Lanceolate	San Rafael Side-notched	Gypsum	San Rafael Stemmed	Elko Series	Rose Spring	Nawthis Side-notched	Bull Creek	Desert Side-notched	Indeterminate stemmed	Indeterminate medium, stemmed	Indeterminate small, triangular	Indeterminate leaf-shaped	Small Anasazi side-notched	Small Anasazi corner-notched	Large Anasazi corner-notched	Indeterminate	Total
42EM1674															2												3	5
42EM1676								1																				1
42EM1677																											1	1
42EM1678													1															1
42EM1679		1																										1
42EM1680																											1	1
42EM1681																					1							1
42EM1685																											2	2
42EM1686												1															2	3
42EM1688														1	1												1	3
42EM1690																											1	1
42EM1691															1													1
42EM1692															4													4
42EM1694		1					1					1			2												3	8
42EM1695															1						1						1	3
42EM1696		1												1	1												3	6
42EM1698													2														1	3
42EM1699															3												1	4
42EM1704																											1	1
42EM1705		1													4												4	9
42EM1706															1						1						1	3
42EM1708																											2	2
42EM1710																							1				1	2
42EM1711																				1								1
42EM1712																											3	3
42EM1713															1												1	2
42EM1714		1																									1	2
42EM1719															1												2	3
42EM1720																											1	1
42EM1723																											1	1
42EM1725																											1	1
42EM1726										1			1														1	3
42EM1727													1		1												3	5
42EM1728															1							1						2
42EM1730													1		1													2
42EM1734														1														1
42EM1735															1												2	3
42EM1736															2					1							2	5
42EM1737																											1	1
42EM1740															1													1
42EM1741															1													1
42EM1742															1												1	2
42EM1743															1													1
42EM1744															4												6	10
42EM1745													1						1								3	5
42EM1746		2													4				1								5	12
42EM1747		4	2	2								1			4												10	23
42EM1748	1																											1
42EM1749																	1										1	2
42EM1751																											1	1
42EM1755																											1	1
42EM1756													1		1												1	3
42EM1757																				1								1
Total	1	11	2	2	0	0	1	1	0	1	0	3	8	3	45	0	1	0	2	3	3	1	1	0	0	0	77	166

Table 63. Frequency of projectile points by site in White Canyon.

Site Number	Lake Mohave	Pinto Series	Sinbad Side-notched	Humboldt Concave Base	Northern Side-notched	Rocker Side-notched	Hawken Side-notched	Sudden Side-notched	Mt. Albion Corner-notched	Oxbow	McKean Lanceolate	San Rafael Side-notched	Gypsum	San Rafael Stemmed	Elko Series	Rose Spring	Nawthis Side-notched	Bull Creek	Desert Side-notched	Indeterminate stemmed	Indeterminate medium, stemmed	Indeterminate small, triangular	Indeterminate leaf-shaped	Small Anasazi side-notched	Small Anasazi corner-notched	Large Anasazi corner-notched	Indeterminate	Total
42SA14405																											2	2
42SA14408																		1										1
42SA14410																									1			1
42SA14411																											1	1
42SA14415																											2	2
42SA14417																											1	1
42SA14418																										2	3	5
42SA14420																						1						1
42SA14421																				1								1
42SA14422						1												1						1	1		3	7
42SA14423												1												1				2
Total	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	0	1	0	1	0	2	2	2	12	24

Table 64. Frequency of projectile points by isolated find in the project area.

Site Number	Lake Mohave	Pinto Series	Sinbad Side-notched	Humboldt Concave Base	Northern Side-notched	Rocker Side-notched	Hawken Side-notched	Sudden Side-notched	Mt. Albion Corner-notched	Oxbow	McKean Lanceolate	San Rafael Side-notched	Gypsum	San Rafael Stemmed	Elko Series	Rose Spring	Nawthis Side-notched	Bull Creek	Desert Side-notched	Indeterminate stemmed	Indeterminate medium, stemmed	Indeterminate small, triangular	Indeterminate leaf-shaped	Small Anasazi side-notched	Small Anasazi corner-notched	Large Anasazi corner-notched	Indeterminate	Total
CC09IF4															1													1
CC22IF4															1													1
CC23IF4																											1	1
CC23IF5															1													1
SR5IF1																			1									1
SR6IF1																											1	1
SR9IF4																											1	1
SR9IF9																											1	1
SR11IF1																											1	1
SR11IF2																											1	1
SR12IF1							1																					1
SR17IF2																											1	1
SR17IF6													1															1
SR23IF2																											1	1
SR27IF5															1													1
SR27IF8																											1	1
SR27IF9																											1	1
SR40IF5													1															1
SR42IF5																											1	1
SR44IF2																											1	1
SR47IF2													1															1
SR48IF3																												
SR48IF4																											1	1
SR48IF5																											1	1
SR48IF6																											1	1
SR49IF2																											1	1
SR53IF1															1													1
SR55IF1																											1	1
SR55IF2																											1	1
SR55IF4																											1	1
SR57IF1																											1	1
SR59IF5															1													1
SR59IF6																											1	1
SR59IF8			1																									1
SR60IF2																											2	2
SR61IF1																											1	1
SR64IF1																											1	1
SR64IF2										1																		1
SR64IF5																											1	1
SR64IF7																											1	1
SR64IF8																											1	1
SR65IF1																											1	1
SR65IF2																											1	1
SR66IF1															1													1
SR66IF2																											1	1
WC1IF1																											1	1
WC1IF2					1										1													2
WC5IF3																											1	1
WC6IF1																											1	1
WC6IF3																											1	1
WC6IF4																											1	1
																									1			1
Total	0	0	1	0	1	0	1	0	0	1	0	0	3	0	8	0	0	0	1	0	0	0	0	0	1	0	36	53

NOTE: CC = Circle Cliffs; SR = San Rafael Swell; WC = White Canyon.

Table 65. Frequency of pottery types by site.

Pottery Type	42SA14404	42SA14405	42SA14406	42SA14407	42SA14408	42SA14409	42SA14410	42SA14411	42SA14412
Anasazi									
Kayenta									
Tusayan Gray Ware-Tsegi Series									
Tusayan Corrugated	x		x		x		x	x	
Indeterminate Corrugated			x	x	x	x	x		x
Tusayan White Ware-Kayenta Series									
Black Mesa Black-on-white					x	x	x	x	
Sosi Black-on-white		x		x	x	x	x	x	
Dogoszhi Black-on-white	x			x	x	x			
Late Pueblo White	x		x	x	x	x		x	x
Polacca Black-on-white									
Tsegi Orange Ware									
Tusayan Black-on-red					x				
Tusayan Polychrome							x		
Late Pueblo Red						x			
Mesa Verde									
Mesa Verde Gray Ware									
Dolores Corrugated	x				x				
Indeterminate Corrugated	x							x	
Mesa Verde White Ware									
Mancos Black-on-white		x							
McElmo Black-on-white	x	x	x	x		x			
Mesa Verde Black-on-white									
Late Pueblo White		x	x		x	x			
Mesa Verde Red Ware									
Early Pueblo Red									
Hopi									
Awatovi Yellow Ware									
Jeddito Corrugated									
Jeddito Yellow Ware									
Jeddito Black-on-yellow									
Fremont									
Parowan									
Utah Desert Gray Ware									
Snake Valley Gray									
Snake Valley Corrugated									
Sevier									
Fremont Gray Ware									
Emery Gray									
Indeterminate									
Indeterminate white	x						x		
Indeterminate gray									
Number of sherds collected	15	4	11	5	23	17	7	11	2
Estimated number of sherds observed	49	7	33	6	129	125	33	33	16

Table 65. Continued.

Pottery Type	42SA14413	42SA14414	42SA14415	42SA14418	42SA14419	42SA14422	42SA14423	42EM1696	42EM1699
Anasazi									
Kayenta									
Tusayan Gray Ware-Tsegi Series									
Tusayan Corrugated		x	x	x			x		
Indeterminate Corrugated		x			x				
Tusayan White Ware-Kayenta Series									
Black Mesa Black-on-white				x					
Sosi Black-on-white	x			x					
Dogoszhi Black-on-white									
Late Pueblo White	x	x		x	x				
Polacca Black-on-white						x			
Tsegi Orange Ware									
Tusayan Black-on-red									
Tusayan Polychrome									
Late Pueblo Red									
Mesa Verde									
Mesa Verde Gray Ware									
Dolores Corrugated									
Indeterminate Corrugated									
Mesa Verde White Ware									
Mancos Black-on-white									
McElmo Black-on-white									
Mesa Verde Black-on-white									
Late Pueblo White									
Mesa Verde Red Ware									
Early Pueblo Red									
Hopi									
Awatovi Yellow Ware									
Jeddito Corrugated						x			
Jeddito Yellow Ware									
Jeddito Black-on-yellow						x			
Fremont									
Parowan									
Utah Desert Gray Ware									
Snake Valley Gray								x	x
Snake Valley Corrugated									
Sevier									
Fremont Gray Ware									
Emery Gray									
Indeterminate									
Indeterminate white									
Indeterminate gray		x							
Number of sherds collected	4	13	3	16	5	7	5	2	4
Estimated number of sherds observed	24	83	20	56	16	12	93	9	11

Table 65. Continued.

Pottery Type	42EM1701	42EM1716	42EM1727	42EM1753	SR-13-IF2	SR-13-IF7	SR-64-IF3	SR-64-IF6
Anasazi								
Kayenta								
Tusayan Gray Ware-Tsegi Series								
Tusayan Corrugated								
Indeterminate Corrugated	x							
Tusayan White Ware-Kayenta Series								
Black Mesa Black-on-white								
Sosi Black-on-white								
Dogoszhi Black-on-white								
Late Pueblo White								
Polacca Black-on-white								
Tsegi Orange Ware								
Tusayan Black-on-red					x			
Tusayan Polychrome								
Late Pueblo Red								
Mesa Verde								
Mesa Verde Gray Ware								
Dolores Corrugated								
Indeterminate Corrugated								
Mesa Verde White Ware								
Mancos Black-on-white								
McElmo Black-on-white					x			
Mesa Verde Black-on-white						x		
Late Pueblo White								
Mesa Verde Red Ware								
Early Pueblo Red					x			
Hopi								
Awatovi Yellow Ware								
Jeddito Corrugated								
Jeddito Yellow Ware								
Jeddito Black-on-yellow								
Fremont								
Parowan								
Utah Desert Gray Ware								
Snake Valley Gray				x			x	x
Snake Valley Corrugated				x				
Sevier								
Fremont Gray Ware								
Emery Gray		x	x					
Indeterminate								
Indeterminate white								
Indeterminate gray								
Number of sherds collected	1	1	1	1	5	1	3	2
Estimated number of sherds observed	1	1	35	6	6	1	15	19

Table 66. Estimation data for number of prehistoric isolated finds by quadrat in the project area.

Study Tract	N	n	x	s^2	$\hat{v}$	$\bar{x}$	95% C.I.
Circle Cliffs and San Rafael Swell	980	98	227	6.35	.06	2.32	± .48
Circle Cliffs	300	30	60	6.90	.21	2.00	± .93
San Rafael Swell	680	68	167	5.98	.08	2.46	± .56
White Canyon	65	7	27	31.81	4.05	3.86	± 4.93

NOTE: N = the total number of quadrats in the sampling universe; n = the number of survey quadrats; x = the number of sites; s^2 = the sample variance; $\hat{v}$ = estimated variance of $\bar{x}$; $\bar{x}$ = the mean number of sites per quadrat; 95% C.I. = the 95% confidence interval.

Table 67. Estimation data for number of prehistoric isolated finds in the project area.

Study Tract	N	n	x	s^2	$\hat{V}$	$\hat{X}$	95% C.I.
Circle Cliffs and San Rafael Swell	980	98	227	6.35	55970	2270	± 471
Circle Cliffs	300	30	60	6.92	18620	600	± 279
San Rafael Swell	680	68	167	5.98	36617	1670	± 383
White Canyon	65	7	27	31.81	17132	251	± 320

NOTE: N = the total number of quadrats in the sampling universe; n = the number of survey quadrats; x = the number of sites; s^2 = the sample variance; $\hat{V}$ = estimated variance of $\hat{X}$; $\hat{X}$ = the estimated population total; 95% C.I. = the 95% confidence interval.

Table 68. Number of prehistoric and historic sites and isolated finds by quadrat in Circle Cliffs.

Quadrat	Sites			Isolated Finds	
	Prehistoric	Historic/Recent	Both	Prehistoric	Historic/Recent
1	0	0	0	1	0
2	2	1	0	3	0
3	4	0	0	6	0
4	0	0	0	1	0
5	6	0	0	3	2
6	0	0	0	0	0
7	6	0	0	2	0
8	0	0	0	0	0
9	3	0	0	5	0
10	2	0	2	1	0
11	2	0	0	0	0
12	0	0	0	0	0
13	0	0	0	0	0
14	1	0	0	0	0
15	0	0	0	0	0
16	4	0	0	0	0
17	1	0	0	1	0
18	5	0	0	10	0
19	2	0	0	0	0
20	0	0	0	1	0
21	0	0	0	2	0
22	4	0	0	4	0
23	0	0	0	5	0
24	3	0	0	0	0
25	1	0	0	0	0
26	2	1	1	7	0
27	0	0	0	1	0
28	1	0	0	0	0
29	1	0	0	1	0
30	0	0	0	6	0
Total	50	1	3	60	2

Table 69. Number of prehistoric and historic sites and isolated finds by quadrat in the San Rafael Swell.

Quadrat	Sites			Isolated Finds		
	Prehistoric	Historic/Recent	Both	Prehistoric	Historic/Recent	Both
1	0	0	0	2	0	0
2	9	0	0	1	1	0
3	0	0	0	4	0	0
4	4	0	0	1	0	0
5	0	0	0	1	1	0
6	0	0	0	1	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	5	0	0	8	2	0
10	1	0	0	0	0	0
11	0	0	0	3	0	0
12	0	0	0	4	0	0
13	0	0	0	9	0	2
14	0	0	0	1	0	0
15	3	0	0	1	0	0
16	0	0	0	0	0	0
17	0	0	0	6	0	0
18	0	0	0	1	0	0
19	0	0	0	0	0	0
20	0	0	0	1	0	0
21	1	0	0	0	0	0
22	1	0	0	1	0	0
23	0	0	0	4	0	0
24	1	0	0	0	1	0
25	1	0	0	2	0	0
26	0	0	0	3	0	0
27	2	0	1	9	0	0
28	1	0	0	0	2	0
29	0	0	0	1	0	0
30	0	0	0	1	0	0
31	0	0	0	1	0	0
32	0	0	0	2	1	0
33	0	0	0	1	3	0
34	0	0	0	0	0	0
35	0	0	0	1	0	0
36	0	0	0	7	0	0
37	0	0	0	2	0	0
38	0	0	0	2	0	0
39	0	0	0	0	0	0
40	1	0	0	5	1	0
41	4	0	0	1	0	0

Table 69. Continued.

Quadrat	Sites			Isolated Finds		
	Prehistoric	Historic/Recent	Both	Prehistoric	Historic/Recent	Both
42	10	0	1	5	0	0
43	0	0	0	2	0	0
44	4	0	0	4	1	0
45	0	0	0	1	0	0
46	0	0	0	0	0	0
47	2	0	0	2	0	0
48	0	0	0	6	0	0
49	2	0	0	2	0	0
50	0	0	0	0	0	0
51	1	0	0	4	0	0
52	0	0	0	4	0	0
53	0	0	0	1	0	0
54	2	0	0	1	0	0
55	3	0	0	6	0	0
56	1	1	0	3	2	1
57	0	0	0	2	0	0
58	0	0	0	1	0	0
59	8	0	0	8	0	0
60	6	0	0	4	0	0
61	0	0	0	1	0	0
62	0	0	0	1	0	0
63	0	0	0	3	0	0
64	2	0	0	8	0	0
65	1	0	0	2	0	0
66	1	0	0	5	0	0
67	0	0	0	4	0	0
68	0	0	0	0	0	0
Total	78	1	2	167	15	3

Table 70. Number of prehistoric and historic sites and isolated finds by quadrat in White Canyon.

Quadrat	Sites		Isolated Finds	
	Prehistoric	Historic	Prehistoric	Historic
1	16	0	16	0
2	1	0	2	0
3	0	0	1	0
4	0	0	0	0
5	0	0	3	0
6	3	0	5	0
7	0	0	0	0
Total	20	0	27	0

APPENDIX 8

A MULTIVARIATE LOCATIONAL MODEL FOR PREHISTORIC OCCUPATION OF THE TAR SANDS AREA, CENTRAL AND SOUTHERN UTAH

by Michael S. Berry and Alan S. Lichty

Appendix 8

A MULTIVARIATE LOCATIONAL MODEL FOR PREHISTORIC OCCUPATION OF THE TAR SANDS AREA, CENTRAL AND SOUTHERN UTAH

Introduction

The survey data reported in the main body of the current study provide an excellent opportunity for experimental work in locational modelling. The approach we advocate is based on the detection of regularities in the co-occurrence of prehistoric archeological sites and distinctive sets of environmental indices. The site distributional data available for the Tar Sands area were derived through the simple random sampling (SRS) procedures described earlier. The environmental indices will be developed in the following sections. These will be derived through multivariate statistical analyses of the LANDSAT data available for the area.

While the conceptual structure of our modelling procedure is simple and straightforward, some of the multivariate techniques are fairly involved. For this reason it will be useful to provide a brief sketch of our general approach before entering into a detailed exposition of the various statistical analyses. Three analytical phases are involved; classification of surveyed quadrats into pseudoenvironmental classes, the recognition of site/environmental associations, and the projection of derived probability statements to unsurveyed portions of the study area.

1. Classification: The LANDSAT data consist of four reflectance bands, each coded from 1 to 127, for each picture element (pixel) in the study area. The first task is to transform the pixel data into 100- by 100-m units to conform with the UTM grid system. Then, the units corresponding to each of the surveyed quadrats are extracted for subsequent processing. In the present case, each quadrat is equal to one quarter section and contains from 72 to 100 transformed pixel units. Hierarchical agglomerative cluster analysis is used to assist in the production of a classification of quadrats based on their respective frequency distributions of "modified"(see discussion below) reflectance values. The relative similarity/dissimilarity of the sample quadrats is indicated by their placement at the terminal nodes of a dendrogram and by the merge sequence depicted in the branching pattern of the dendrogram. If the survey region is sufficiently well structured in terms of reflectance zonation, the cluster analysis yields fairly tightly defined pseudoenvironmental groups of quadrats. If, on the other hand, the survey region is relatively homogeneous the dendrogram will form an unanalyzable "chaining" pattern. In such cases, there is little reason to continue the analysis since the likelihood of relating site location to environmental variation in any meaningful way is markedly diminished.

2. Recognition of Association: Given that the dendrogram does, in fact, display significant structuring, the next step is to search for interesting co-occurrences of sites and

environmental groups or classes. This is accomplished simply by indicating the presence/absence or abundance of sites in each of the quadrats. Data sets most amenable to locational modelling are those that (1) have one or more environmental classes in which high percentages of the constituent quadrats contain sites *and*, (2) have one or more environmental classes in which most of the quadrats are devoid of sites. When such circumstances obtain, the percentages of quadrats containing sites for each environmental class are calculated. These are termed the "empirical probabilities" of site occurrence by quadrat class.

3. Projection: The LANDSAT derived quadrat data for the environmental classes are then subjected to discriminant analysis. If successful (i.e., if the analysis supports the validity of the postulated group structure), the discriminant classification equations are used to classify an additional set of unsurveyed quadrats, equal in number to the surveyed quadrats. The probabilities of class membership generated by the discriminant classification algorithm for each quadrat are then multiplied by the appropriate "empirical probabilities" to yield the joint probability of site occurrence for all of the quadrats in the unsurveyed group. Similar calculations are performed for the surveyed quadrats to create "fictive" probabilities in order to produce a regional sensitivity map. This is accomplished with an interpolative mapping routine using all the assigned probability values for the surveyed and unsurveyed quadrats.

Modelling Procedures

The field survey was conducted in three widely separated areas and it would not be reasonable to suppose that a single model could be developed for all three survey regions. Further, the White Canyon sample consists of only seven quadrats. This would be insufficient for locational modelling and would lead to spurious results. For these reasons, only the San Rafael Swell (n=68) and Circle Cliffs (n=30) survey areas will be subjected to locational analyses and a separate model will be developed for each.

Data Extraction Methods

The data used for environmental analysis in the Tar Sands study areas were extracted from two LANDSAT tapes. The LANDSAT data are from the scenes 2200717191, dated July 21, 1980, and 2200717185, exposed July 20, 1980. The dates of these scenes were chosen on the basis of midsummer vegetation coupled with good-quality exposures without cloud cover. For the actual data extraction, we utilized the Earth Resources Laboratory Applications Software (ELAS) which has recently been adapted for use on the University of Utah College of Science's DEC System 20-60 mainframe computer.

Since the original pixel data are not oriented to convenient mapping units for purposes of this study, we utilized application modules within the ELAS package to resample the pixel data for all spectral bands into 100 m^2 data cells oriented to the UTM grid coordinate system. This was accomplished by identifying 15 pixels referenced by actual UTM grid coordinates for each of the 2 pictures on gray-scale printouts and then using a least squares fitting method, data points were refined until the 15 reference points resulted in a usable root mean square error. The pixel values were resampled with a bilinear interpolation technique included in the ELAS package. For a detailed description of the mathematical modelling techniques used in this set of tasks, the reader is referred to the appendices of the ELAS User's Guide (Report No. 183).

These procedures resulted in separate data sets for each of the three study areas. Data for the San Rafael Swell study area cover from 500000E to 555000E and from 4270000N to 4330000N. Data for the Circle Cliffs study area range from 480000E to 510000E and from 4160000N to 4200000N. White Canyon data were extracted as per description above, but the number of quadrats was deemed to be too small for subsequent analysis.

The surveyed quadrats were digitized into the UTM grid system via a digitizing table and the resulting "polygons" were used as input data for extracting the surveyed pixels. A pixel cell was defined as being part of the quadrat if the quadrat boundaries passed through any portion of the cell. All pixel cells for each quadrat were written into another data file which was the basis for subsequent analysis. Due to major inconsistencies within the cadastral grid system and differences between the UTM grid and the cadastral coordinates from the field survey work, it was not possible to hold the number of pixels per quadrat constant. Pixels per quadrat range from 72 to 100. This did not cause any analytical difficulties.

The San Rafael Swell Model

Data Reduction and Modification: Following extraction and resampling of the pixel data, we sought to represent each pixel by a single index rather than the original four-scaled variables. This was accomplished through principal components analysis, using SPSS subprogram FACTOR (PAI) (Nie et al. 1975) (Table 71). Since the first principal component (Factor 1) explained 91.8% of the variance, the use of the first principal component score in place of the original four variables for each pixel seemed warranted. Accordingly, these scores were written to a disk file for the 5636 cases.

We next calculated the distributional statistics (i.e., the mean, standard deviation, kurtosis, skewness and range) for the 72 to 100 principal component scores for each of the surveyed quadrats. These statistics were to be treated as input "variables" for subsequent cluster and discriminant function analyses as described earlier. (In the remaining discussion, we adopt the convention of italicizing the five relevant statistics when referring to them as variables. Otherwise they retain their usual meaning as descriptive statistics.) However, it was first necessary to check each variable for normality since the probability assignments of discriminant classification are based on the assumption of a multivariate normal distribution. As Cooley and Lohnes (1971:38) note, univariate normality of all the variables involved does not guarantee multivariate normality. However, we do know that if any of the variables are badly skewed then multivariate normality is an impossibility. We are better off, then, to inspect the univariate distributions and apply normalizing transformations where appropriate. We used the STAT80 interactive package (Fullerton 1982) for this purpose since it offers a histogram routine that superimposes a normal curve on the empirical frequency distribution. The *mean* and *skewness* statistics proved to be normally distributed across the 68 cases (quadrats). However, the *standard deviation*, *kurtosis* and *range* all exhibited positive skewing which was remedied with common logarithmic transformations. Once these modifications had been made the data were ready for additional manipulation.

Cluster Analysis: The five variables were standardized to zero mean and unit variance and then used as input for cluster analysis. We employed squared euclidean distance and Ward's minimum variance clustering algorithm (Anderberg 1973). The resultant dendrogram is shown in Figure 32. The terminal nodes are labeled with the appropriate quadrat designation and the number of prehistoric sites found in each quadrat is shown in parentheses. The line of asterisks represents the cut points for a four class-solution. We initially had opted for a two-class solution which combined Classes 1 and 2 and Classes 3 and 4. Discriminant function

Table 71. Principal components analysis of the San Rafael Swell pixel data.

Variable	Factor	Eigenvalue	% of Variance	Cumulative %
Var1	1	3.67153	91.8	91.8
Var2	2	0.21956	5.3	97.3
Var3	3	0.08110	2.0	99.3
Var4	4	0.02781	0.7	100.0

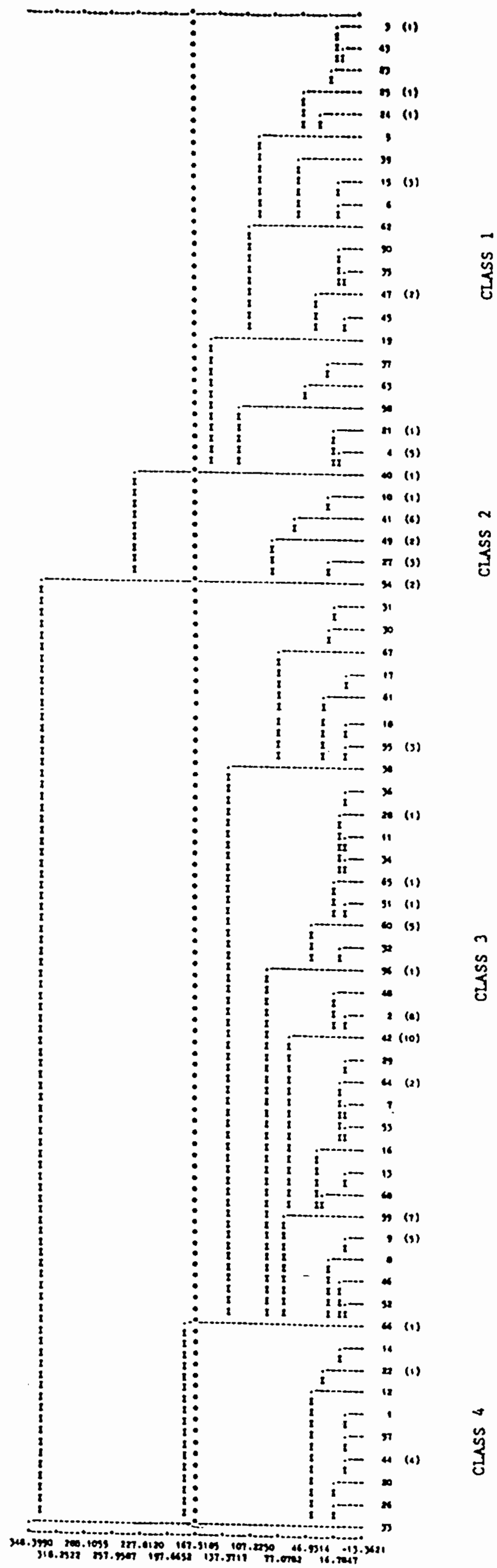

Figure 32. Dendrogram of 68 surveyed quadrats in the San Rafael Swell area.

analysis was used to assess the distinctiveness of these two groups. *Range* and *kurtosis* proved to be the most powerful discriminating variables and reclassification of the original data set yielded the results presented in Table 72.

While this was undoubtedly an acceptable classification rate, the four-group solution was to be preferred if similar discrimination could be obtained since it would allow for an improved partitioning of site concentrations. Discriminant analysis at the four-class level gave the prediction matrix presented in Table 73.

This is only slightly less efficient than the two-class performance. The first two discriminant functions accounted for most of the discriminating power (96.06% cumulative relative eigenvalue). *Standard deviation*, *kurtosis* and *range* were the most important variables on the first function and *range* was the only important variable on the second.

Table 72. Two-group discriminant analysis of San Rafael Swell site location.

	No. of	Predicted Group Membership	
Actual Group	Cases	Group 1	Group 2
Group 1	26	6	0
		100.0%	0.0%
Group 2	42	2	40
		4.8%	95.2%

Percent of "grouped" cases correctly classified: 97.06%

Table 73. Four-group discriminant analysis of San Rafael Swell site location.

	No. of	Predicted Group Membership			
Actual Group	Cases	Group 1	Group 2	Group 3	Group 4
Group 1	21	20	0	0	1
		95.2%	0.0%	0.0%	4.8%
Group 2	5	0	5	0	0
		0.0%	100.0%	0.0%	0.0%
Group 3	33	0	0	30	3
		0.0%	0.0%	90.9%	9.1%
Group 4	9	0	0	0	9
		0.0%	0.0%	0.0%	100.0%

Percent of "grouped" cases correctly classified: 94.12%

The "empirical probabilities" for the four classes were calculated by dividing the number of quadrats per class containing sites by the total number of quadrats per class. These are Class 1 = 0.381, Class 2 = 1.000, Class 3 = 0.364, Class 4 = 0.222.

Discriminant Classification of Unsurveyed Quadrats: Pixel data for an additional 66 quadrats (5383 pixels) within the San Rafael Swell survey area were extracted and modified in the same manner as the original data set. These quadrats were then treated as "unknowns" in a subsequent four-class discriminant run which assigned them to the nearest predetermined class centroid. Figure 33 shows the distribution of quadrat types (including both surveyed and unsurveyed) over the study area. In order to generate a site sensitivity map, the appropriate "empirical probabilities" were multiplied by the probability of group membership listed in the discriminant classification output. As shown in Figure 34, the frequency distribution of these joint probabilities is trimodal. The low grouping ranges from 0.129 to 0.260. The next ranges from 0.300 to 0.390. Finally, there is a very high grouping of nine cases which ranges from 0.869 to 1.000. It should be noted that we have not calculated confidence intervals for the joint probabilities and that they, therefore, must be interpreted with appropriate caution. Much greater sample sizes would be required to warrant such calculations. Nonetheless, the distribution of probabilities demonstrates interesting patterning that should prove useful for land management planning.

Figure 35 is a sensitivity map designed for such planning purposes. It was created by plotting the probabilities of site occurrence in the center of each quadrat and then submitting this data array to an interpolative plotting routine. The results may be used as a general indicator of where sites may or may not be found and will allow land managers to assess the likely impacts of development within the survey area. Needless to say, such assessment does not carry over into the arena of "remote clearance" and under no circumstances should this map be used to write-off areas of low projected probability.

The substantive interpretation of the areal distribution of locational probabilities must, of course, be left to those with first hand knowledge of the San Rafael Swell study area. Our contribution is essentially an exercise in "blind" modelling and we are not in possession of sufficient information to attempt ground-truthing or to discuss the nature of the resource base associated with the LANDSAT variables. We will, however, offer a few observations on the interpretation and expectations of locational modelling in general in a later section of this paper.

The Circle Cliffs Model

The identical procedures used in the San Rafael Swell modelling process were for the Circle Cliffs data set. It will suffice to summarize the results without repeating the underlying assumptions of the techniques or detailing the conventions adopted.

Data Reduction and Modification: The Circle Cliffs data consisted of 30 quadrats ranging from 72 to 90 resampled pixels each. The total number of pixels in this data set was 2511. Data reduction was again accomplished through principal components analysis (Table 74).

The first principal component explained 88.7% of the variance. While this is was not quite as efficient as the results obtained for the San Rafael Swell area, it was still sufficient to warrant the use of only a single principal component score per pixel in subsequent analyses.

We next calculated the mean, standard deviation, kurtosis, skewness and range for the principal component scores for each quadrat and inspected the distribution of each of these statistics over all 30 cases. The *means*, *skewnesses* and *ranges* were normally distributed across cases, however *standard deviation* and *kurtosis* required common logarithmic conversion.

Cluster Analysis: The five normalized variables were standardized to zero mean and unit variance and the cases were clustered, again using squared euclidean distance and Ward's minimum variance method. The resultant dendrogram is shown in Figure 36. This represents a fairly clear-cut three-class solution. The terminal nodes are labeled with the Circle Cliffs

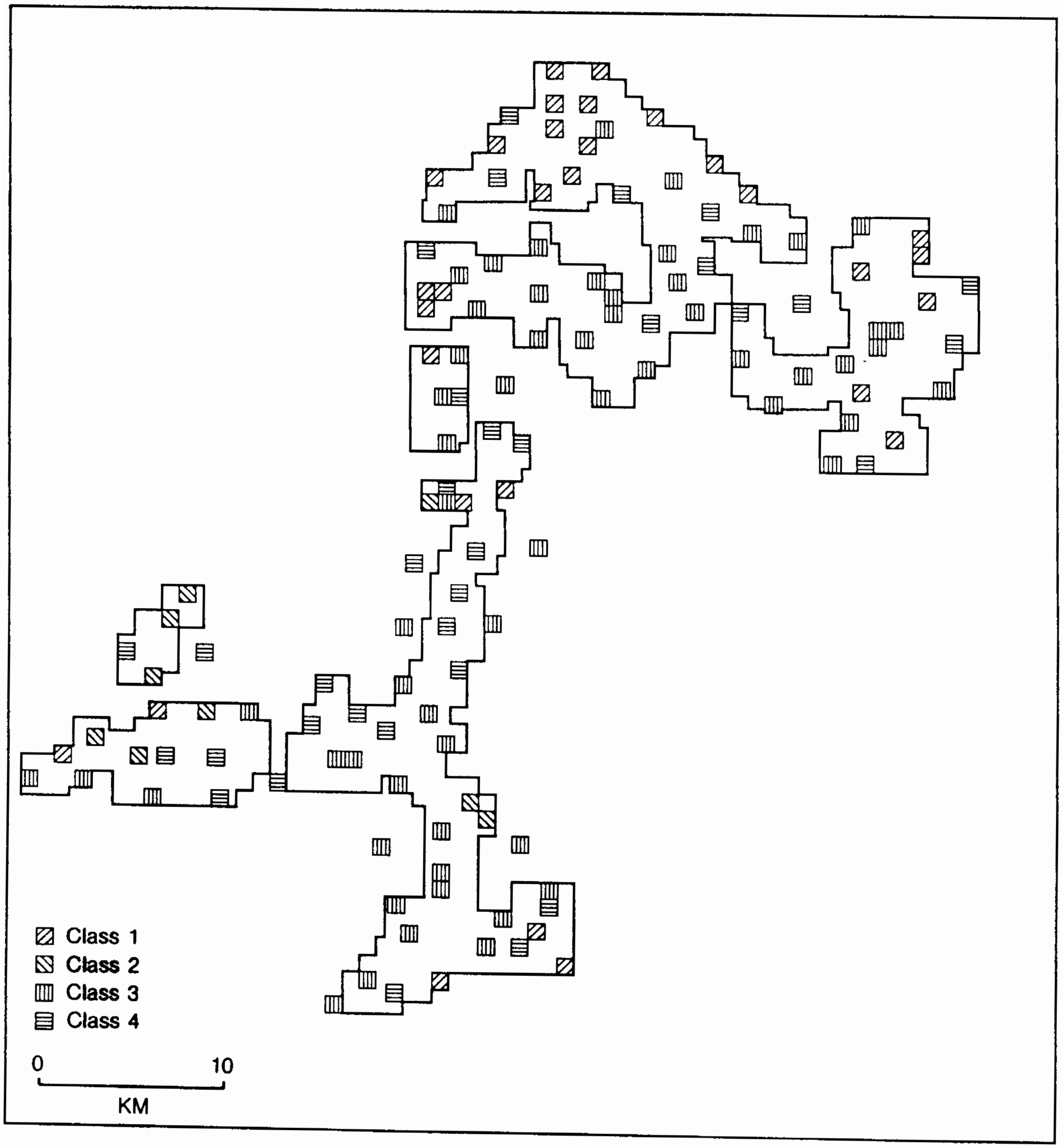

Figure 33. Location of San Rafael Swell quadrat classes.

```
        Probability
No.      Interval          Histogram

 5     0.129 - 0.172 |****
21     0.172 - 0.216 |*****************
14     0.216 - 0.260 |************
 4     0.260 - 0.303 |***
25     0.303 - 0.347 |**********************
56     0.347 - 0.390 |**************************************************
 0     0.390 - 0.434 |
 0     0.434 - 0.477 |
 0     0.477 - 0.521 |
 0     0.521 - 0.565 |
 0     0.565 - 0.608 |
 0     0.608 - 0.652 |
 0     0.652 - 0.695 |
 0     0.695 - 0.739 |
 0     0.739 - 0.782 |
 0     0.782 - 0.826 |
 0     0.826 - 0.869 |
 1     0.869 - 0.913 |*
 0     0.913 - 0.957 |
 8     0.957 - 1.000 |*******
                     |.........|.........|.........|.........|.........|
                     0         11        22        33        44        55
                                   Each * = 1.120 Cases
```

Figure 34. Frequency distribution of San Rafael Swell quadrat probabilities.

quadrat designations and the number of sites per quadrat is indicated in parentheses. Using these three classes as "groups," we submitted the normalized data to discriminant function analysis with the classification results presented in Table 75.

Two functions were required to discriminate the three classes. *Range* and *skewness* were the most significant variables on the first function, while *range*, *mean* and *standard deviation* were the dominant variables on the second. The first function accounted for 76.49% of the relative eigenvalue.

The "empirical probabilities" for the three classes were calculated as before. These are Class 1=0.636, Class 2=0.750, Class 3=0.455. These are not nearly as well differentiated as in the San Rafael Swell case but they should still be useful.

Discriminant Classification of Unsurveyed Quadrats: Pixel data for an additional 30 quadrats (2448 pixels) within the Circle Cliffs survey area were extracted and modified in the same manner as the original data set. These "unknown" quadrats were then assigned to the three classes defined for the surveyed quadrats via discriminant classification (Figure 37). The joint probabilities of site occurrence were then calculated as before. The frequency distribution of probabilities across the 60 cases is shown in Figure 38.

Again, the distribution is trimodal. The low grouping ranges from 0.177 to 0.292. The next ranges from 0.329 to 0.597, and the high grouping ranges from 0.597 to 0.750. Figure 39 is a

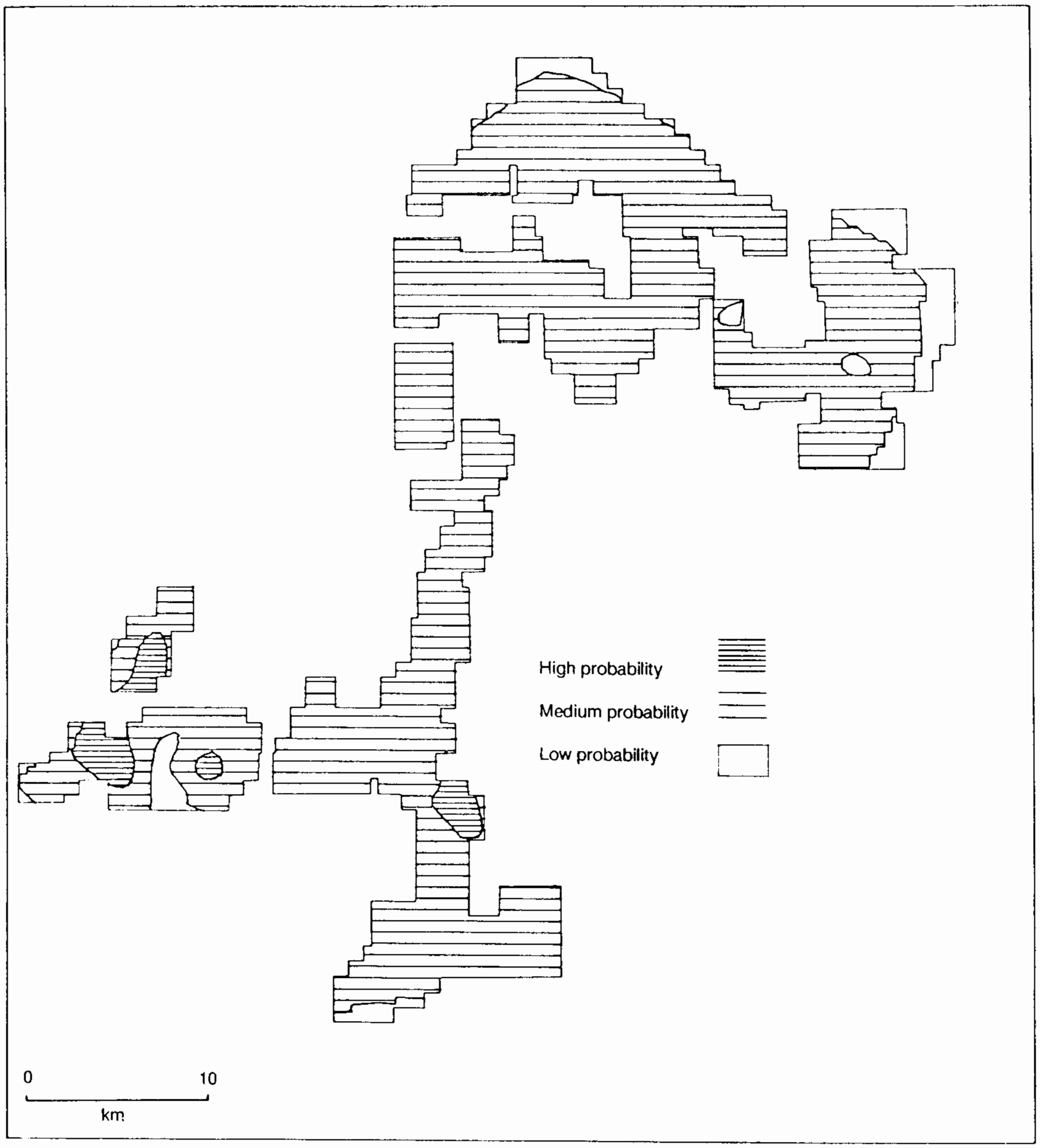

Figure 35. Sensitivity map of the San Rafael Swell area.

Table 74. Principal components analysis of the Circle Cliffs pixel data.

Variable	Factor	Eigenvalue	% of Variance	Cumulative %
Varl	1	3.54748	88.7	88.7
Var2	2	0.35978	9.0	97.7
Var3	3	0.06076	1.5	99.2
Var4	4	0.03198	0.8	100.0

sensitivity map based on the interpolative plotting of the quadrat probabilities.

An Alternative Approach

The methods outlined above are relatively new and still in the experimental stage. The only previous application of this type of locational modelling was for a project in China Lake, California (Elston et al. 1983). A more typical approach is the one favored by Holmer (1979), Kvamme (Burgess et al. 1980), Peebles (1981), Larralde and Chandler (1981) and Zier and Peebles (1982), in which discriminant function analysis is performed without any prior consideration to the natural patterning of environmental variation. The "groups" used in the analysis are determined solely on the basis of site presence or absence and the discriminant algorithm is expected to isolate the critical environmental variables responsible for site location. This two-group discriminant approach typically produces poor results in terms of reclassification of the initial data set and it can therefore be expected to perform even less efficiently in the "prediction" of unknown quadrats (Cooley and Lohnes 1971:262-63). For example, reclassification of the original data sets yielded a 76.5% success rate for Holmer's (1979) model and only 69.5% for Zier and Peebles (1982). When it is considered that 50% overall classification should occur due to chance alone, these figures are not terribly impressive. It seems likely that small departures from chance classification percentages may reflect nothing more than idiosyncratic environmental variation between the site and nonsite groups, variation that had nothing to do with prehistoric site settlement. If so, these models can be very misleading and they will serve neither management nor research goals in an adequate manner.

As an experiment, we coded the 68 quadrats from the San Rafael Swell survey in terms of site presence/absence and performed two-group discriminant analysis. The results are presented in Table 76. This is obviously not a very efficient classification performance, although it is in line with the "predictive" models mentioned above. It is interesting to note that the most important variable in the standardized discriminant function is *skewness* whereas we have demonstrated above that *range* is consistently the most significant variable for distinguishing between groups defined on environmental bases. This discrepancy, combined with the low classification rate and the very low canonical correlation of 0.291, suggests that this particular analysis is meaningless.

In order to further investigate the potential of the two-group approach, we attempted another analysis using environmental variables recorded during the survey rather than the LANDSAT data. Seven interval scale variables including relief (elevational range), mean elevation, distance to river, distance to permanent water, aspect, distance to pinyon-juniper zone and number of drainages within a quadrat were selected for analysis. In addition, we used all 105 quadrats from the San Rafael Swell and Circle Cliffs as well as the White Canyon study areas. Quadrats with sites were coded as Group 1 and those without sites were coded as Group 2. The most significant variable on the standardized discriminant function was mean elevation and 68.57% of the quadrats were correctly classified.

At this point, we began to suspect that 60-70% might actually be the "default" success rate

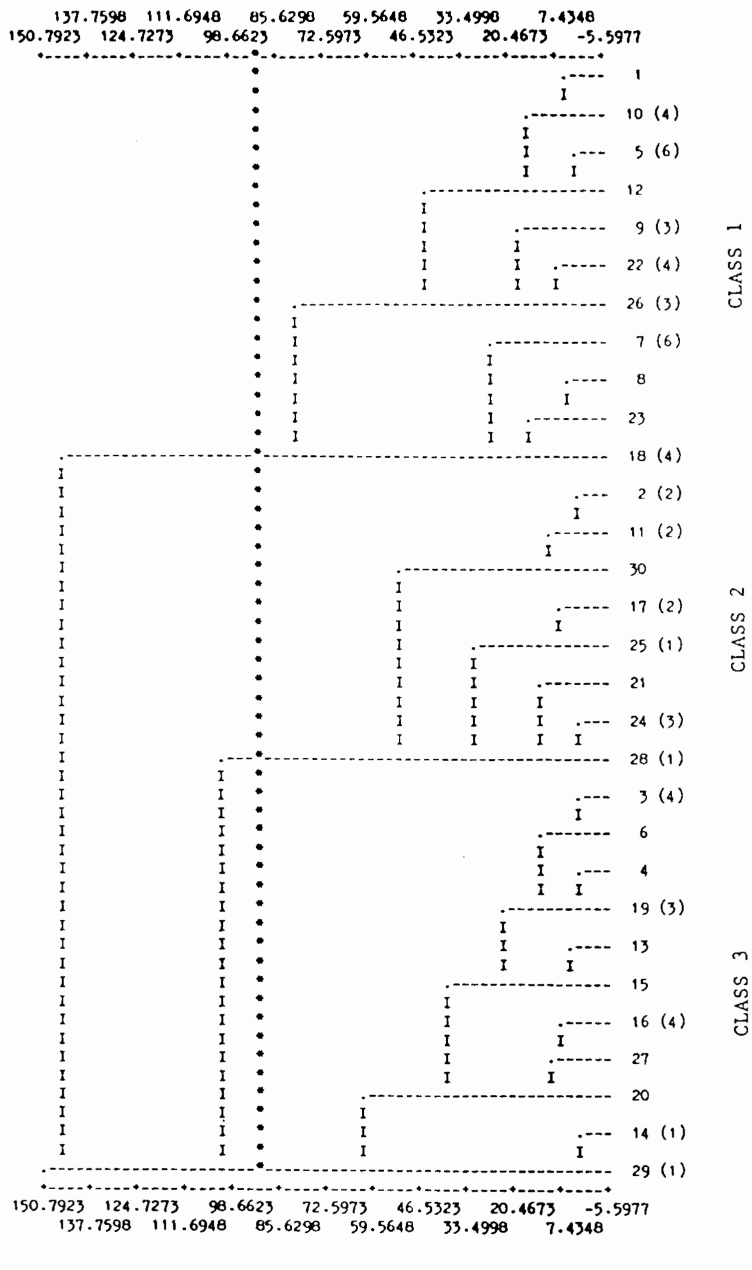

Figure 36. Dendrogram of 30 surveyed quadrats in the Circle Cliffs area.

Table 75. Three-group discriminant analysis of Circle Cliffs sites location.

Actual Group	No. of Cases	Predicted Group Membership Group 1	Group 2	Group 3
Group 1	11	10	0	1
		90.9%	0.0%	9.1%
Group 2	8	0	8	0
		0.0%	100.0%	0.0%
Group 3	11	0	0	11
		0.0%	0.0%	100.0%

Percent of "grouped" cases correctly classified: 96.67%

for virtually any two-group partition. To examine this possibility, we performed another run on the same 105 quadrats. However, this time we arbitrarily encoded the first 48 cases as Group 1 and the remaining 57 cases as Group 2 without concern for site content. This resulted in a 70.48% correct classification rate. Two additional runs with different, but wholly arbitrary group definitions yielded 66.67% and 74.29% correct classifications. It appears from this exercise that our suspicions were warranted. It is very difficult to produce a two-group discriminant result *lower than 70%*. Those responsible for producing such models should no longer point to classification performances in this range as evidence of success. In all likelihood, the results obtained to date with models of this particular genre are of little value.

Discussion

The combination of cluster analysis and discriminant function analysis appears to be a useful approach to environmental classification of LANDSAT data. This is evident in the spatial patterning of quadrats as indicated in Figures 33 and 37. In the San Rafael Swell example, Classes 1 and 2 are statistically similar as shown in the cluster analysis (Figure 32). Yet they are spatially clustered at, respectively, the northern and southern ends of the study tract. This suggests that our techniques are capable of detecting subtle variations in environmental "signatures." This distinctive areal patterning stands out in contrast to the apparently random distribution of Class 3 and Class 4 quadrats. It would be most interesting to conduct ground-truthing surveys with botanists and geologists in order to discover the underlying causes of these patterns, especially in light of the fact that prehistoric site selection was influenced to some extent by this environmental variability. The same is true for the Circle Cliffs study area where two spatial clusters of Class 2 quadrats were separated by a block of Class 1 quadrats. In this case, Class 3 quadrats appear as random background "noise."

The sensitivity maps shown in Figures 35 and 39 combine the information from Figures 33 and 37 with the archeological data recorded during the survey. Probability configurations do not necessarily coincide with quadrat class distributions since the former is only partially dependent upon the latter. As noted earlier, these maps should be useful to land managers for planning purposes. The greatest benefit will probably come early in the planning process for

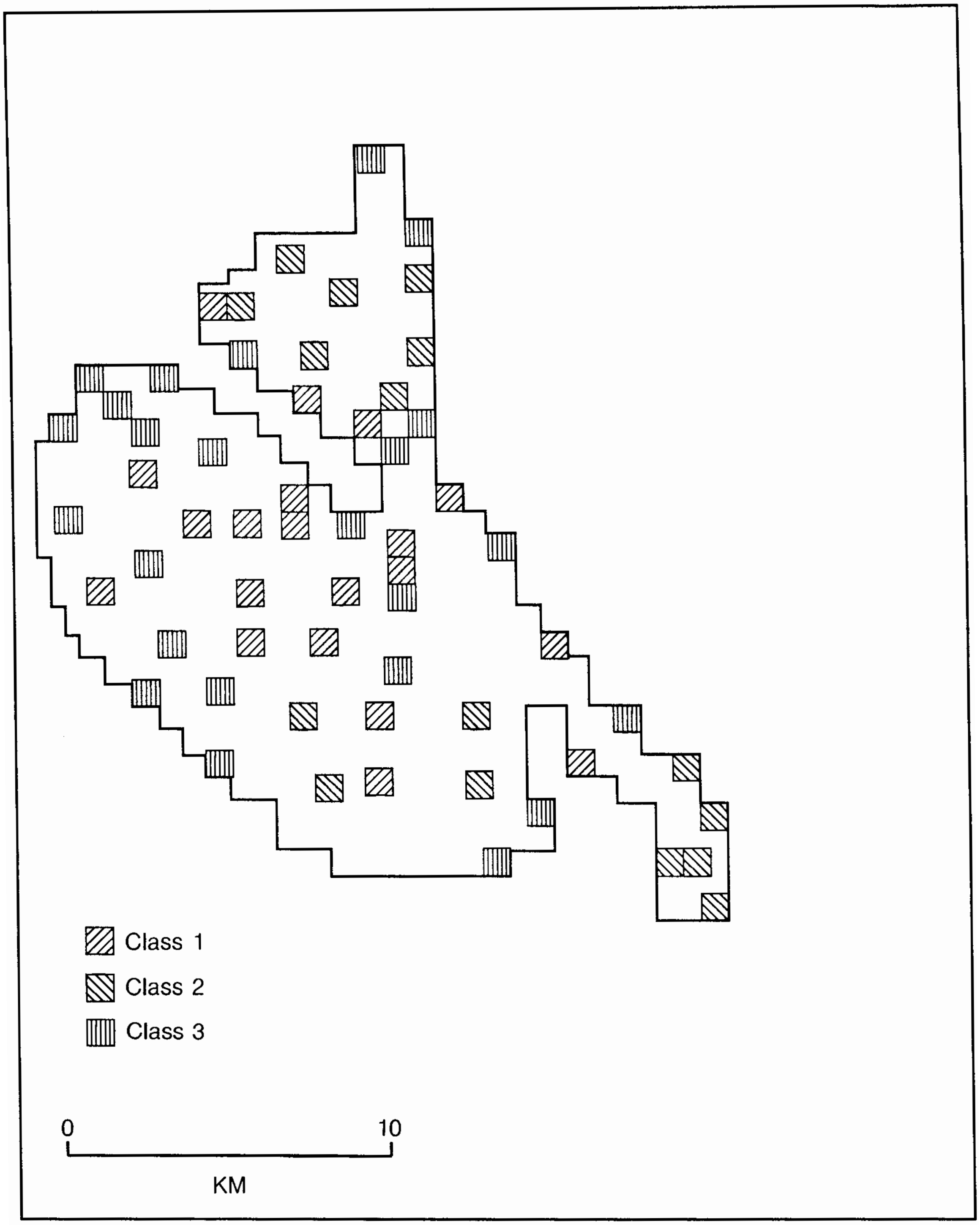

Figure 37. Location of Circle Cliffs quadrat classes.

```
       Probability
No.     Interval            Histogram

 1     0.177 - 0.215 |*
 1     0.215 - 0.253 |*
 4     0.253 - 0.292 |****
 0     0.292 - 0.330 |
 1     0.330 - 0.368 |*
 2     0.368 - 0.406 |**
 5     0.406 - 0.444 |*****
10     0.444 - 0.483 |**********
 2     0.483 - 0.521 |**
 2     0.521 - 0.559 |**
 1     0.559 - 0.597 |*
10     0.597 - 0.635 |**********
10     0.635 - 0.674 |**********
 3     0.674 - 0.712 |***
 8     0.712 - 0.750 |********
                     |.........|.........|
                     0        10        20
                       Each * = 1.000 Cases
```

Figure 38. Frequency distribution of Circle Cliffs quadrat probabilities.

large-scale earth-disturbing projects when, typically, a number of alternative project localities are considered. The costs of survey and mitigation in high-probability site areas may well enter into the decision to eliminate certain localities in favor of low-probability areas.

We must again stress that neither of these models is offered as a replacement for survey work once the land manager has made a decision to impact a given region. There is absolutely no way of assigning a zero probability to any of the quadrats. Quite to the contrary, as indicated in the frequency distributions of Figures 34 and 38, the vast majority of quadrats in both the San Rafael Swell and Circle Cliffs areas have non-negligible probabilities of site occurrence.

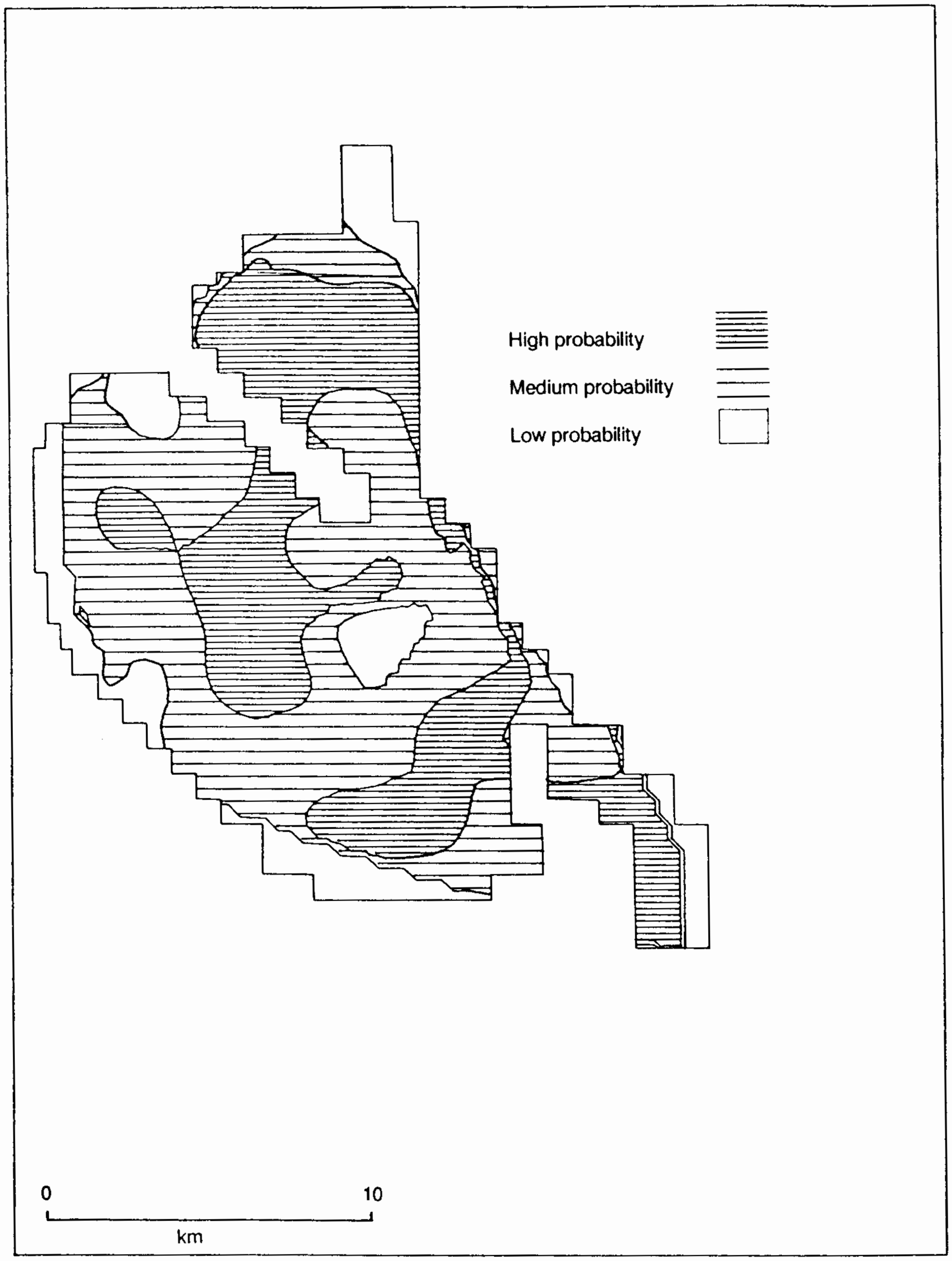

Figure 39. Sensitivity map of the Circle Cliffs area.

Table 76. Two-group discriminant analysis of San Rafael Swell data.

Actual Group	No. of Cases	Predicted Group Membership: Sites	Predicted Group Membership: Non-Sites
Sites	27	14	13
		51.9%	48.1%
Non-sites	41	14	27
		34.1%	65.9%

Percent of "grouped" cases correctly classified: 60.29%

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